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SALMON HABITAT RESTORATION COST MODELING: RESULTS AND LESSONS LEARNED

K. Kelly Hildner
Cynthia J. Thomson

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

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K. Kelly Hildner
Cynthia J. Thomson

National Marine Fisheries Service,NOAA
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, California 95060

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U.S. DEPARTMENT OF COMMERCE
Carlos M. Gutierrez, Secretary
National Oceanic and Atmospheric Administration
VADM Conrad C. Lautenbacher, Jr., Undersecretary for Oceans and Atmosphere
National Marine Fisheries Service
William T. Hogarth, Assistant Administrator for Fisheries

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Abstract

This report describes results of a pilot study involving use of data contained in the California Habitat Restoration Project Database (CHRPD) to characterize salmon habitat restoration projects and to model restoration costs. We supplemented data from the CHRPD with project data acquired through forms sent to contractors. Our analysis yielded some significant results regarding the effects of project characteristics, prevailing economic conditions, and landscape characteristics on restoration costs. However, data limitations hampered our ability to conduct multivariate analysis and to fully consider the potentially confounding effects of often highly correlated cost factors.

Modeling capability would be greatly enhanced if funding entities were to establish routine information requirements for restoration proposals and contract reports based on (1) standard protocols for disaggregating restoration costs (typically reported at the project level) among the site-specific tasks that comprise the project, and (2) comprehensive, well-defined and standardized methods of characterizing the amounts and types of work completed under each task. Such standardization would also facilitate the ability of funding entities to summarize and track the cumulative effects of their programs; such accountability is important, given the substantial public monies being spent on restoration.

Restoration costs should ideally be linked to salmon population changes or to reductions in limiting factors affecting salmon survival and recovery. Given the spatial linkages between upstream/downstream and upslope/downslope habitat conditions, it is not always possible to evaluate the effect of any single restoration project on limiting factors without considering the larger spatial context within which it occurs. Further research that focuses more on networks of spatially linked projects and associated costs may be useful in this regard.

Background

There are ten California salmonid stocks currently listed as threatened or endangered under the Endangered Species Act (ESA), and many hundreds of millions of dollars have been spent on restoration efforts to date. NOAA Fisheries is working on comprehensive recovery plans for salmon and steelhead to provide a framework for addressing problems in a way that covers entire geographic areas, addresses all threats, and prioritizes actions necessary for recovery. Recovery plans for California salmonids are focused on 4 geographic areas, or domains: Southern Oregon/Northern California Coast, North-central California Coast, South-central California Coast, and Central Valley. The ESA requires that, among other things, recovery plans contain an estimate of the cost and time required to carry out recovery actions. This document reflects part of ongoing efforts to devise methods of estimating the component of recovery costs pertaining to habitat restoration.

While restoration project costs are best estimated on the basis of detailed ground surveys and budgets tailored to the specific project, our purpose was not to provide precise, project-specific cost estimates but rather to conduct an exploratory analysis of factors hypothesized to affect restoration costs. Our original plan was to use readily available data on past restoration projects to create a set of mathematical models that would allow us to predict the costs of future restoration projects from a set of easily acquired project variables. We found, however, that the available data was not adequate for the type of modeling desired. The best available data on salmonid habitat restoration in California is the California Habitat Restoration Project Database (CHRPD, http://www.calfish.org/DesktopDefault.aspx?tabId=60), a cooperative project originally funded by NOAA Fisheries, currently funded by the California Department of Fish and Game, and managed by the Pacific States Marine Fisheries Commission. This database was created in 1999, partially for the purpose of compiling restoration cost data for analysis, and has since become a useful tool for managing restoration grants and archiving information about restoration projects. The CHRPD serves many useful purposes, but in its current form it lacks the level of specificity of cost data we need for our habitat restoration cost analyses.

The reasons we have had difficulty using the CHRPD for our analyses are threefold. First, the cost information stored in the database is not broken out by location (site) and type of restoration. There are many projects in the database that occur at multiple sites and include multiple types of restoration work, but cost information is available only at the project level. Second, given the manner in which measurements of project size are stored in the database, it is difficult or impossible to derive consistent and accurate unit costs for restoration work. For example, in some cases there are many different measurement units in the database for the same treatment, and these units are not explicitly defined, so in some cases it is impossible to tell which units are comparable. Also, there can be multiple, nonexclusive measurements for each site, but there is no basis by which to partition costs among the different measurements. Third, the data on types of restoration work are not well classified for analysis. There are too many treatment types (105) and they are not explicit or rigorous enough to separate projects into meaningful categories.

To overcome the difficulties outlined above, we decided to collect additional data from restoration contractors on a subset of projects from the CHRPD. Here we describe the data collection methodology, the data we received, the resulting cost analysis, and recommendations for future data collection and analysis.

Data Collection

In this section we outline our methods for data collection including selecting restoration tasks and predictor variables, choosing projects for further data collection, and creating forms for the data collection.

Selecting Restoration Tasks and Predictor Variables

Restoration Tasks

There are many ways to categorize types of restoration work. In the CHRPD, restoration sites are categorized by habitat category and by treatment. Habitat categories are broad categories of restoration work, some emphasizing location (such as instream) and others emphasizing type of work (such as roadwork). Including 'Unknown', there are 14 habitat categories in the database (Table 1). Each site in the CHRPD is assigned one or more habitat categories. Treatments in the CHRPD refer to the specific types of restoration work that were done at the site. There are 105 possible treatment types in the database (Table 2). Each site in the database is assigned one or more treatments depending on the types of restoration work that were done at that site for that project.

For analyzing the cost of restoration projects, we created an additional categorization of restoration types based on general categories of restoration work that we call tasks (Table 3). We created this categorization to group the large number of restoration treatments into a more manageable number of on-the-ground restoration types for analysis purposes. See Table 2 for a mapping of CHRPD treatments to tasks. Note that many of the treatments from the CHRPD do not fit into any of the tasks.

Table 1. Habitat categories from the CHRPD

Habitat Category ID	Habitat Category
1	Instream
2	Riparian
3	Upland
12	Instream and Riparian
24	Wetland
25	Estuary
26	Road
27	Rearing
28	Monitoring and Research
29	Education
30	Watershed Assessment
31	Watershed Organization Support
32	Acquisition of Land or Water
99	Unknown

Table 2. Treatments from the CHRPD and their corresponding tasks.

DetailsID	Treatment	TaskID	Task
5	Pool created (unknown method)		
10	Off-channel habitat created (alcove, side channel, pond)		
16	Spawning gravel placed in stream		
18	Fish trapped for survey or rearing		
24	Off-channel habitat reconnected or access improved (alcove, side channel, etc.)		
29	Loosened/cleaned spawning gravels (gravel ripping)		
32	Main stream channel modified/created		
33	Improve ford (low water crossing)		
39	Bridge installed		
40	Culvert or other stream crossing removed and not replaced		
54	Pool excavated or blasted		
55	Carcasses or other nutrients added to stream/bank		
58	Fence maintenance		
59	Livestock access/crossing created or improved		
65	Invasive plant control		
97	Other treatment (enter further information in comments)		
99	Unknown		
103	Livestock rotation		
104	Beavers introduced		
107	Livestock off-channel watering facility developed		
115	Grass planted		
118	Sediment-trap dam installed		
119	Sediment removed from stream		
205	Harvest/land management practices changed		
209	Mine site restored		
302	Upland erosion control		
303	Upland vegetation management changed		
306	Agricultural or grazing practices modified		
401	Dike breached		
402	Wetland created		
403	Previously filled or drained wetland restored		
404	Existing wetland improved		
407	Wetland vegetation planted		
502	Water right purchased or leased		

DetailsID	Treatment	TaskID	Task
503	Repair/maintenance of existing restoration project structure (non-dam)		
601	Estuarine area created		
603	Previously filled or drained estuary restored		
604	Freshwater flow in estuary increased		
10001	Restoration project effectiveness monitoring		
10002	Watershed organization support		
30000	Survey, study, research		
30003	Education, training, workshops		
30005	Educational video, display, interpretive facilities		
30007	Salmon enhancement: Collect/raise/transport/plant fish		
30008	Watershed assessment and planning		
30011	Wildlife management, trapping, transport (except beaver introduction)		
30013	Monitoring of watersheds and fisheries		
30015	Salmon enhancement: Fish marking and technology		
30022	Salmon enhancement: facillities		
30023	Irrigated new plantings		
106	Fencing/livestock exclusion	1	Fencing Projects
41	Trees planted (unknown type)	2	Riparian Planting
42	Planting (unknown type)	2	Riparian Planting
101	Conifers planted	2	Riparian Planting
102	Hardwood stand converted to conifers	2	Riparian Planting
105	Hardwoods planted	2	Riparian Planting
117	Willows planted (simple planting, not bioengineering)	2	Riparian Planting
121	Shrubs or herbaceous vegetation planted	2	Riparian Planting
34	Culvert replaced with bridge	3	Culvert Replacement
35	Culvert replaced with open-bottom arch culvert	3	Culvert Replacement
36	Culvert replaced with closed-bottom culvert (round or pipe-arch)	3	Culvert Replacement
62	Culvert replaced with box culvert	3	Culvert Replacement
63	Culvert replaced with open-bottom box culvert	3	Culvert Replacement
64	Culvert replaced with closed-bottom box culvert	3	Culvert Replacement
30021	Culvert/bridge upgraded (unknown method)	3	Culvert Replacement
37	Culvert retrofitted with baffles or weirs	4	Existing Culvert Improvement
38	Weir installed below culvert outlet	4	Existing Culvert Improvement
1	Large wood anchored in place (log, rootwad)	5	Instream Structures
2	Rootwads placed in stream	5	Instream Structures
4	Log weir installed (not below culvert)	5	Instream Structures
8	Boulders placed in stream	5	Instream Structures
9	Brush bundles placed in stream	5	Instream Structures

DetailsID	Treatment	TaskID	Task
11	Rock weir installed (not below culvert)	5	Instream Structures
12	Flow deflector installed (type unspecified)	5	Instream Structures
31	Concrete weir installed (not below culvert)	5	Instream Structures
47	Large wood placement (not anchored, or not known if anchored)	5	Instream Structures
48	Weir installed (unknown type, not below culvert)	5	Instream Structures
52	Flow deflector installed: log	5	Instream Structures
53	Flow deflector installed: rock/boulder	5	Instream Structures
30019	Flow deflector installed: rock and log	5	Instream Structures
30020	Pool created using scour structure	5	Instream Structures
7	Stream bank stabilized (unknown method)	6	Bank Stabilization
17	Stream bank stabilized: rock gabion installed	6	Bank Stabilization
49	Stream bank stabilized: log revetment installed	6	Bank Stabilization
50	Stream bank stabilized: rock and log revetment installed	6	Bank Stabilization
51	Stream bank stabilized: bioengineering (living building materials)	6	Bank Stabilization
116	Stream bank stabilized: riprap (rock revetment) installed	6	Bank Stabilization
120	Stream bank stabilized: stream bank resloped	6	Bank Stabilization
206	Road decommissioned/obliterated	7	Road Decommissioning
201	Road modified to reduce impacts to streams	8	Road Surface Upgrade/Maintenance
202	Road ditch and drainage culvert maintenance (removing debris)	8	Road Surface Upgrade/Maintenance
203	Road drainage culvert installed/replaced/improved	8	Road Surface Upgrade/Maintenance
501	Land purchased, leased, or easement acquired	9	Land Acquisition
28	Water management (storage and release timing)	10	Water Conservation Measures
61	Irrigation water recycled (tailwater recaptured)	10	Water Conservation Measures
304	Irrigation system improved	10	Water Conservation Measures
15	Fish screen installed	11	Fish Screens
14	Fish ladder installed	12	Fish Ladders
23	Fish ladder improved	12	Fish Ladders
20	Pushup dam permanently removed	13	Barrier Removal
21	Fish barrier removed (type unknown)	13	Barrier Removal
56	Log jam removed	13	Barrier Removal
57	Dam removed	13	Barrier Removal
112	Dam repaired	13	Barrier Removal
602	Tidegate altered/removed	13	Barrier Removal

Table 3. Restoration tasks.

TaskID	Task
1	Fencing Projects
2	Riparian Planting
3	Culvert Replacement
4	Existing Culvert Improvement
5	Instream Structures
6	Bank Stabilization
7	Road Decommissioning
8	Road Surface Upgrade/Maintenance
9	Land Acquisition
10	Water Conservation Measures
11	Fish Screens
12	Fish Ladders
13	Barrier Removal

Predictors of Restoration Cost

In order to model costs, it is necessary to identify factors that are significant predictors of cost for the restoration tasks identified above. The factors affecting cost generally differ for different types of restoration work. For each restoration task, we developed a list of possible cost predictors for use in our analyses. Resources used to help determine appropriate predictors and their corresponding factor levels included Evergreen Funding Consultants (2003), Flosi et al. (2002), and personal communication with California Department of Fish and Game fish habitat specialists.

Below are summaries of the cost factors identified for each type of restoration task. We developed cost models for eight of these tasks (fencing, riparian planting, culvert replacement, culvert improvement, instream structures, bank stabilization, road decommissioning, road upgrade/maintenance). Data for some of the factors associated with these tasks (shown below in bold) were obtained from contractors (see Appendix 1). For other factors (shown below in italics) we used surrogate measures that could be acquired using Geographical Information Systems (GIS). Other factors were omitted for practical reasons – e.g., because they would require detailed project budgeting or because they would make it difficult for us to keep our data collection forms as simple and brief as possible to avoid overburdening potential respondents.

For a variety of reasons (e.g., lack of data, expectation that cost factors would likely be too variable or site-specific for modeling), cost modeling was not attempted for the remaining tasks. However, potential cost factors are described for two of these tasks (land acquisition, water conservation) - for those who may be interested in pursuing their own cost analysis of these tasks. Summary information from the CHRPD on one of these tasks (land acquisition) is also provided.

<u>Fencing Projects (for each site):</u>

1. **Cost**
2. **Length of fencing (lineal feet)**
3. **Fencing Materials (simple, average, complex)**

    - **simple = barb or hog wire, no gates, few posts**
    - **average = livestock fence, metal, wood or metal corners, few gates, moderate number of posts**
    - **complex = smooth wire, new Zealand type, deer exclusion, curtain type**

4. **Fence Electrified (yes/no)**
5. Spacing of posts (lineal feet)
6. Clearing needed (light, average, heavy)
7. *Slope (flat, average, steep)*
8. Site preparation difficulty (flat/light clearing, average slope/average clearing, steep/heavy clearing)
9. *Labor cost/type (low/volunteer, medium/conservation corps, high/contracted)*
10. *Labor rate ($/hour and number of man hours)*
11. Longevity (estimate years to replacement)
12. Maintenance (annual cost)

<u>Riparian Planting – not including road decommissioning projects (for each site)</u>

1. **Cost**
2. **Area planted (area and fraction planted)**
3. **Trees planted**
4. **Site accessibility (easy, average, difficult)**
    - **easy = easily accessible by vehicle**
    - **average = site partially accessible by vehicle**
    - **difficult = very limited access, no vehicle access**
5. **Materials cost (minimal, moderate, substantial)**
    - **minimal = bare roots; most materials donated; native materials readily available**
    - **moderate = bare root; weed block: landscape fabric, mulch; combination of donated and purchased materials; native materials less readily available**
    - **substantial = 1 - 5 gallon and greater size plants; weed block: landscape fabric and mulch; majority of materials purchased; native materials not readily available or grown by seed collection**
6. Clearing needed (light, average, heavy)
7. *Slope (flat, average, steep)*
8. **Site preparation difficulty (easy, moderate, difficult)**
    - **easy = flat/light clearing, soil easily tilled**
    - **moderate = average slope/average clearing, average soil**
    - **difficult = steep/heavy clearing, soil difficult to till**
9. *Labor cost/type (low/volunteer, medium/conservation corps, high/contracted)*
10. *Labor rate ($/hour and number of man hours)*

11. Design/permitting (simple, average, complex)
12. Irrigation (annual cost)
13. **Irrigation needs**
    - **Minimal – not needed**
    - **Moderate – drip line from public/private source**
    - **Substantial – solar irrigation, water truck, hand watering**
14. Years of maintenance required (including protection from deer browse)

<u>Culvert Replacement – not including road decommissioning projects (for each culvert)</u>

1. **Cost**
2. **Type of road (forest road, minor 2 lane, major 2 lane, highway 4+ lane)**
3. Valley width – channel width (ft) downstream of culvert at high water mark
4. **Size of culvert to be installed (inches)**
5. *Stream flow (CFS)*
6. **Culvert replaced by bridge (yes/no)**
7. **Fill height – distance from top of culvert to road (feet)**
8. Was instream work also done above or below the culvert? (yes/no)
9. Maintenance (annual cost)
10. Longevity (estimate years to replacement)
11. Presence of phone and/or electrical lines at the crossing (yes/no)
14. Traffic control required? (yes/no)

<u>Existing Culvert Improvement – not including road decommissioning projects (for each culvert)</u>

1. **Cost**
2. **Type of improvement (angle iron, chimney block, baffles)**
3. **Was instream work done above or below the culvert? (yes/no)**
4. **Delivery / transport distance**
5. **Length of culvert (feet)**
6. *Stream flow (CFS)*
7. Maintenance (annual cost)
8. Longevity (estimate years to replacement)
9. Presence of phone and/or electrical lines at the crossing (yes/no)

<u>Instream Structures – not including bank stabilization (for each structure or stream mile)</u>

1. **Cost**
2. **Project size (stream miles for LWD; number of structures for complex, engineered structures)**
3. *Stream flow (CFS)*
4. **Material type (wood, boulders, both, bioengineered)**
5. **Boulder material size (diameter)**
6. **Log size (diameter)**
7. **Stream size (small, medium, large)**

- **Small, 1st order**
- **Medium, 2nd order**
- **Large, 3rd order and above**

8. **Distance to materials source (miles)**
9. **Transportation (easy/near 0-7 miles, average access/average distance 7-20 miles, difficult/far 20+ miles**
10. *Design costs/risk of accident or flooding (minimal, moderate, substantial)*
    - *minimal = small remote streams*
    - *moderate = intermediate level of use*
    - *substantial = heavily used rivers and those bordered by rural and suburban communities*
11. Helicopter needed? (yes/no)
12. Longevity (estimate years to replacement)
13. Maintenance (annual cost)

Bank Stabilization – not including riparian planting or instream structures

1. **Cost**
2. **Size of project (linear feet)**
3. **Size of waterway (small, medium, large)**
    - **small = 1st order**
    - **medium = 2nd order**
    - **large = 3rd order and above**
4. Was the streambank resloped? (yes/no)
5. **Extent of placement/excavation (minimal, moderate, substantial)**
    - **minimal = hand tools**
    - **moderate = small equipment, moderate excavation**
    - **substantial = heavy equipment, reconstruction of slope**
6. **Materials (minimal, moderate, substantial)**
    - **minimal = Native and channel gravel or rock is utilized, available onsite**
    - **moderate = riprap, vegetated with onsite plants**
    - **substantial = large logs (>24 inch diameter), large rootwads, large toe rock; offsite plants**
7. Longevity (estimate years to replacement)

Road Decommissioning

1. **Cost**
2. **Length of road (miles)**
3. **Type of decommissioning (complete obliteration, partial, closure only)**
4. *Number of treatment sites*
5. **Number of stream crossings**
6. **Depth of culvert fill (feet)**
7. Equipment cost including transportation(minimal, moderate, substantial)
8. **Transport distance for materials (rock) (miles)**
9. Hauling of fill required? (yes/no; amount)

10. **Site accessibility/access road condition (low, medium, high)**
11. Type of road (dirt, asphalt)
    - Minimum: ranch roads
    - Moderate: skid roads
    - Maximum: Asphalt, legacy, Humboldt crossings
12. *Geology/landform stability/past failures from road system*
13. *Slope (from GIS)*

<u>Road Surface Upgrade/Maintenance (not including culverts)</u>

1. **Cost**
2. **Road length treated (miles)**
3. **Type of upgrade (road drainage, outsloping, drc's (ditch relief culverts), rolling dips, waterbars, other)**
4. **Transport distance for materials**
5. **Site accessibility (low, medium, high)**
6. *Slope (from GIS)*
7. *Soil erodibility (from GIS)*
8. Longevity (estimate years to replacement)

<u>Land Acquisition</u>

1. Cost
2. Land use/development potential/zoning (forest, agriculture, rural, suburban, urban)
3. Amenity value for developed land (low, medium, high, very high)
   - low = parcel on small creek
   - medium
   - high
   - very high= highly sought-after waterfront property
4. Level of improvements/access (minimum, moderate, maximum)
   - minimum = unimproved parcel with difficult access
   - moderate = intermediate access and some improvements
   - maximum = good road access and all utilities in place
5. Proximity to urban areas (far, medium, near)
   - far = 41+ miles
   - medium = 21-41 miles
   - near = 0-20 miles
6. Presence of sensitive areas – wetlands, floodplains, steep slopes, etc.
7. Conservation easement? (yes/no, number of years)
8. Current land use in effect (forest, agriculture, rural, suburban, urban)

Water Conservation Measures

1. Cost
2. Type
    - Diversion ditch piping/lining
    - Livestock watering systems
    - Water purchase or long-term lease
    - Tailwater management
3. Net cfs gain

Restoration categories for which cost factors were not developed

1. Fish screens
2. Fish ladders
3. Barrier removal

Choosing Projects for Further Data Collection

We used the CHRPD (1/6/05) to select a subset of projects for collecting further information. CDFG staff recommended that we only look at the most recent projects because 1) contractors would have more information readily available for projects that they are actively working on or have recently finished, and 2) recent projects would reflect the current best practices for restoration. For this reason, we limited our projects for data collection to those from fiscal year 2002/2003 and 2003/2004. Projects from a narrow range of years are also more likely to be consistent in terms of economic conditions that could affect costs, including prevailing wage laws. We also focused only on projects for which CDFG is the data source and that involved certain selected restoration tasks.

These criteria resulted in the selection of a total of 169 projects encompassing 2331 sites for which to gather additional data. The number of projects for each of the selected restoration tasks is shown in Table 4. Table 5 shows the number of projects by number of sites per project. The number of sites for each of the selected restoration tasks is shown in Table 6.

Table 4. Number of projects by task for the subset of projects selected for further data collection. There are a total of 169 projects, many of which match multiple tasks.

TaskID	Task	Number of Projects
1	Fencing Projects	20
2	Riparian Planting	77
3	Culvert Replacement	45
4	Existing Culvert Improvement	4
5	Instream Structures	75
6	Bank Stabilization	86
7	Road Decommissioning	36
8	Road Surface Upgrade/Maintenance	53

Table 5. Number of projects by number of sites per project for the subset of projects selected for further data collection.

Number of Sites per Project	Number of Projects
1	90
2	15
3	5
4	4
5	4
6	5
7	1
8	1
9	3
10	4
12	2
13	1
14	1
16	1
19	1
20	1
22	1
24	2
25	1
27	1
28	1
29	1
31	1
32	3
33	2
34	1
37	1
39	2
44	1
54	1
59	1
61	1
75	1
88	1
89	2
99	1
111	1
181	1
209	1
262	1

Table 6. Number of sites by task for the subset of sites selected for further data collection. There are a total of 2331 sites, many of which match multiple tasks.

TaskID	Task	Number of Sites
1	Fencing Projects	27
2	Riparian Planting	237
3	Culvert Replacement	207
4	Existing Culvert Improvement	4
5	Instream Structures	581
6	Bank Stabilization	450
7	Road Decommissioning	934
8	Road Surface Upgrade/Maintenance	1143

Forms for Data Collection

A primary consideration in creating forms for data collection was simplifying the forms and minimizing the number of questions to avoid over-burdening contractors and to increase response rates. For this reason, as we discussed above, we reduced the number of predictors for which we asked contractors to provide information. For final predictors and factor levels, see the forms in Appendix 1. For each contact person, we created a packet that included a cover letter, an instruction sheet, a map of the sites from the database, one or more project level forms, and site level forms for each site. Individuals in the third mailing (see below) were also sent a list of all sites in each project.

Packets were sent out in three phases. The phases were selected based on the number of sites per person in our subset of projects described above. Forms were revised slightly for each phase. In the first phase, packets were sent to individuals with 3 or fewer sites. These individuals were asked to provide data for all of the sites in the packet. The second phase mailing included individuals with greater than 3 sites but less than 15 sites and was broken into two subgroups: those with less than 6 sites and those with greater than or equal to 6 sites. Individuals with fewer than 6 sites were asked to provide data for all of the sites in the packet, and individuals with 6 or more sites were asked to provide data for all of the sites if possible and otherwise to provide data for the 5 sites that that they felt were most representative of their work. The third phase mailing included individuals with 15 or more sites. These individuals were asked to provide information on 5 sites that are representative of the projects provided and were encouraged to provide additional data if possible (Table 7).

Examples of forms and documents mailed to contractors can be found in Appendix 1.

Table 7. Numbers of contacts in each phase of the data request mailing and the total number of projects and sites represented in each phase.

Mailing	Number of Contacts	Number of Projects	Number of Sites
First Phase	51	55	63
Second Phase	21	49	147
Third Phase	26	65	2121
Total	*98*	*169*	*2331*

The number and types of projects and sites in the database changed somewhat as the data collection progressed because some individuals provided updated site information that may have involved removing and/or adding sites, and others substituted data on projects they had already completed if the projects originally requested were not finished. Some contacts with additional projects were also added.

Sources of Error

There are many potential sources of error both in our data and our analyses. Here we briefly describe some of these sources.

Sources of Error in Restoration Data

The data we received from contractors may have errors and/or inconsistencies resulting from idiosyncrasies in our forms, differences in contractors' interpretation of our questions, differing definitions of sites, vagueness in categorizations, and/or the unfinished state of many of the restoration projects.

One possible error associated with the design of our forms involved our use of check boxes on the forms. There were several questions asked as check boxes including whether contractors were required to pay prevailing wages, whether materials were available onsite for instream structure installation projects, and whether fences were electrified in the fencing projects. Upon receiving the data, we realized that these check boxes result in ambiguous data because there is no way of knowing whether an empty box indicates a negative response or whether the respondent failed to answer the question.

A potential source of inconsistency in the data involves the interpretation by the respondent of how to partition the cost data for the project. The respondent was asked to provide the costs only for the tasks occurring at the site in question and to include labor, equipment, materials, and in-kind contributions in the cost values. It is possible that some respondents either included additional costs such as permitting costs or left out some costs that may have been difficult to partition among sites. Any differences among contractors in interpretation or execution of the partitioning of costs among sites and tasks would increase the error in the resulting database.

Another source of inconsistencies in the data is differences in the way that sites are defined. We used the site locations provided in the CHRPD database. There are not clear guidelines for how sites are defined, so for example some projects will include each instream structure location as a separate site while others will group multiple instream structures into a single site.

Yet another source of error is the creation of factor levels and other categorizations for partitioning the data. Criteria definitions may not be explicit or rigorous enough to separate the projects into meaningful categories. Both the creation of factor levels and the categorization of types of restoration work may result in artificial data groupings that could lead to spurious data correlations. In some cases, such as for the road upgrading projects (see road upgrading analysis below), we did not receive enough data for each type of work to analyze each type separately. Lumping all of the types together for analysis could lead to spurious correlations with predictor variables.

In addition to the above sources of error, there is also error associated with the uncertainty of cost values for projects that have not been completed. We chose to ask contractors for data on the most recent projects in order to get the most up-to-date cost information and the most detailed data. One drawback of this approach, however, is that many of the projects were not yet completed, so the cost values are estimates and may not accurately reflect the final costs of the projects.

Sources of Error in Spatial Analyses

Spatial Uncertainty: For some of our analyses we used Geographical Information Systems (GIS) software and data to relate restoration sites to certain socioeconomic and environmental predictor variables, such as unemployment rates and slope of the terrain. The spatial location of each restoration site is stored in digital form as a point, line, or polygon. The spatial uncertainty in these data, as well as in the GIS data for predictor variables can lead to errors. For example, the digitized locations for the restoration sites may not accurately represent the project boundaries. In some cases locations probably underestimate the extent of the project's spatial coverage (particularly for sites digitized as points) and in others the spatial extent may encompass far more area than where the actual work took place. These inaccuracies will lead to errors when the spatial locations are used to determine the values of predictor variables using GIS.

Regionalization Problems: Creation of artificial zones to describe certain characteristics of the landscape, such as soil types and erodibility factors, are an over-simplification and generalization of reality and may lead to errors because large-scale (detailed) variability and gradual changes are not captured.

Uncertainty in Vector Data Structure: Socioeconomic data may be forced into zones whose boundaries may not respect natural distribution patterns. For example, the population density data that we collected for our analyses provides estimates of population density for polygons representing US Census Bureau incorporated and designated places and balance of county areas. The population density for each polygon is an attribute of the entire polygon even though the population is probably not spread out evenly within that polygon.

Missing Values: Typically imputing missing values and then conducting analyses as if the imputed values were actual data is better than deleting samples, but methods for taking imputation into account can be complex (see Harrell, 2001, Chapter 3). Imputation of missing values for each variable in each restoration type was beyond the scope of this project. For each test below, we deleted samples with missing values for the variables in that test. The reader should be aware that patterns in missingness of variables could affect the interpretation of the results.

Response Rates and Data Analyses

Overall Response Rates

Table 8 indicates the response rates of the people contacted from the original subset of projects selected for additional data collection. Some of the people who did not respond no longer worked for the grant-receiving agency. In some of those cases, other individuals provided information about those projects, but they are not included in the table below.

Table 8. Number and percentage of responses with useable data from the original packets sent.

Mailing	**Number of Original Contacts Providing Useable Data**	**Number of Projects**	**Number of Sites**
First Phase	16 (31%)	19 (35%)	23 (37%)
Second Phase	14 (67%)	32 (65%)	74 (50%)
Third Phase	11 (42%)	26 (40%)	55 (3%)
Total	*41 (42%)*	*77 (46%)*	*152 (7%)*

Overall, we received data for 228 sites in 103 projects (Table 9). Some of these projects are not included in the above table because they were added by contractors but were not in the original selected set of projects. Others were in the original set, but someone other than the original contact person provided the data.

Table 9. Number and percentage of projects and sites in the new database for which we received responses.

	Total	Responses Received With Data	Responses Received Without Useable Data	No Response	Response For Other Sites But Not This One
Projects	178	103 (58%)	18 (10%)	57 (32%)	
Sites	2330	228 (10%)	80 (3%)	894 (38%)	1128 (48%)

Data and Analyses

All statistical analyses for this report were conducted using R Version 2.2.0 (R Development Core Team, 2005). Data on socioeconomic and environmental variables were associated with restoration sites using ArcGIS Version 9.1 (ESRI, 2005).

Here we summarize the data received for each restoration task along with some analyses of restoration cost. Recall that it is possible to have multiple tasks at the same site. The sites in the database each have from 0 to 5 of the 8 tasks for which we requested data (Table 10).

Table 10. Number of sites by number of tasks for which we received data from contractors.

Number of Tasks	Number of Sites
0	2101
1	176
2	28
3	17
4	5
5	2

Our intention was to use the data collected from this effort to create linear models that could be used to help predict the costs of future restoration work. The small sample sizes and high variability of the data, however, made this approach impracticable. Here we summarize the data for each restoration type by a variety of different predictor variables and present results of some linear regression analyses.

Fencing Projects

We received data on 11 sites that included cost information associated with fencing. The sites are from 10 projects; one project had two sites with fencing data. Number of sites and cost statistics are reported in Table 11.

Table 11. Summary of fencing cost per foot.

Number of Sites	Minimum Cost per Foot	Maximum Cost per Foot	Average Cost per Foot	Standard Deviation of Cost per Foot
11	$0.79	$7.00	$3.95	1.84

For comparison, we also looked at the cost per foot of fencing for projects in the original CHRPD from 3/14/05 (Table 12). Cost data in the CHRPD are recorded at the project level. To attempt to get accurate values of cost per foot of fencing, we limited the projects to those with only one task (fencing), one measurement type, and one site per project. We also only looked at projects that began in 1998 or later. None of the selected sites from the CHRPD are the same as those in the new database. The average cost per foot of fencing was higher in the projects from the CHRPD. It is possible that aspects of the project other than fencing may have been included in the total project cost in the CHRPD.

Table 12. Summary of fencing cost data from the CHRPD (3/14/05). Sites are limited to projects since 1997 with only one task (fencing), one measurement type, and one site per project.

Number of Sites	Minimum Cost per Foot	Maximum Cost per Foot	Average Cost per Foot	Standard Deviation of Cost per Foot
9	$2.43	$22.07	$7.24	5.93

<u>Analysis</u>

As was mentioned above, new data that we collected from contractors included 11 sites with fencing data, from 10 different projects. Most statistical analyses require independence of samples, and clearly samples from the same project are not independent. So, for statistical analyses we randomly selected one site from each project and used this subset of the data for our analyses.

Fence Length

There was not a significant association between cost per foot of fencing and the length of fencing installed (Regression, P = 0.28).

Fencing Materials

We asked restoration contractors to provide the material complexity of the fencing materials they used:

- simple = barb/hog wire, no gates, few posts
- average = livestock fence, metal, wood/metal corners, few gates, moderate # of posts
- complex = smooth wire, New Zealand/curtain type, deer exclusion).

Of the 11 fencing sites for which we have cost data, 2 were classified as simple, 7 as average, and 2 as complex (Table 13). In our random sample of one site from each project, 2 were classified as simple, 6 as average, and 2 as complex. There was not a statistically significant difference in cost among the different fence material types, but the sample size is small (Kruskal-Wallis, P = 0.186, n = 10; Figure 1).

Table 13. Fencing cost by materials category for the complete dataset.

Fence Material	Number of Sites	Minimum Cost per Foot	Maximum Cost per Foot	Average Cost per Foot	Standard Deviation of Cost per Foot
Simple	2	$0.79	$3.00	$1.89	1.56
Average	7	$2.00	$7.00	$4.32	1.70
Complex	2	$3.44	$6.00	$4.72	1.81

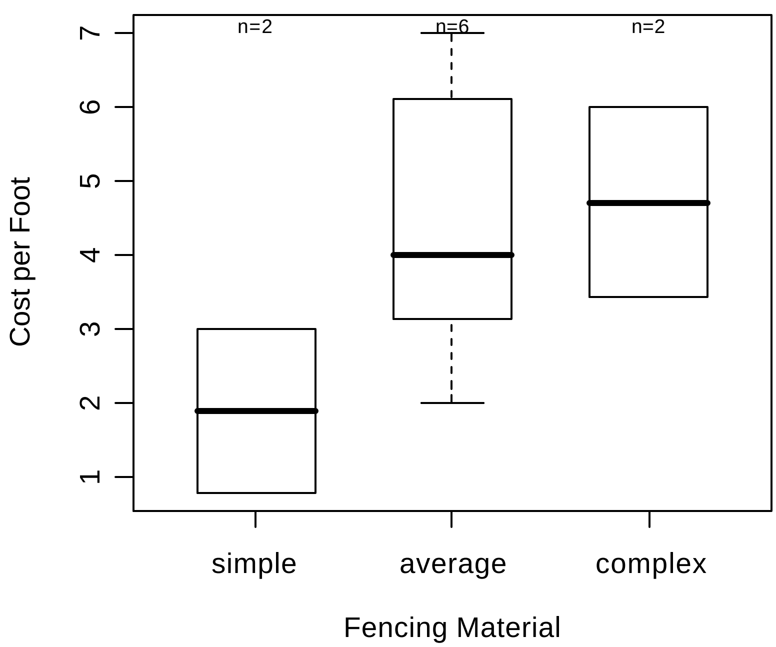

Figure 1. Box plot of cost per foot of fencing for the different fencing materials categories.

We also asked contractors whether or not the fencing was electrified. 3 of the fencing sites involved electrified fencing and 8 involved fencing that was not electrified (Table 14). In our random sample of one site from each project, 3 of the fencing sites involved electrified fencing and 7 involved fencing that was not electrified. Electrified fences cost significantly less per foot on average than non-electrified fences (Wilcoxon signed rank test, W = 21, P = 0.022; Figure 2). The effect of electrification may be confounded with material complexity, as only fences of simple or average complexity were electrified; no complex fences were electrified (Table 15).

Table 14. Fencing cost by electrification status for the complete dataset.

Electrified	Number of Sites	Minimum Cost per Foot	Maximum Cost per Foot	Average Cost per Foot	Standard Deviation of Cost per Foot
Yes	3	$0.79	$3.00	$1.93	1.11
No	8	$3.15	$7.00	$4.71	1.44

Table 15. Fencing cost by electrification status and materials category for the complete dataset.

Electrified	Fence Material	Number of Sites	Minimum Cost per Foot	Maximum Cost per Foot	Average Cost per Foot	Standard Deviation of Cost per Foot
Yes	simple	2	$0.79	$3.00	$1.89	1.56
Yes	average	1	$2.00	$2.00	$2.00	
No	average	6	$3.15	$7.00	$4.71	1.49
No	complex	2	$3.44	$6.00	$4.72	1.81

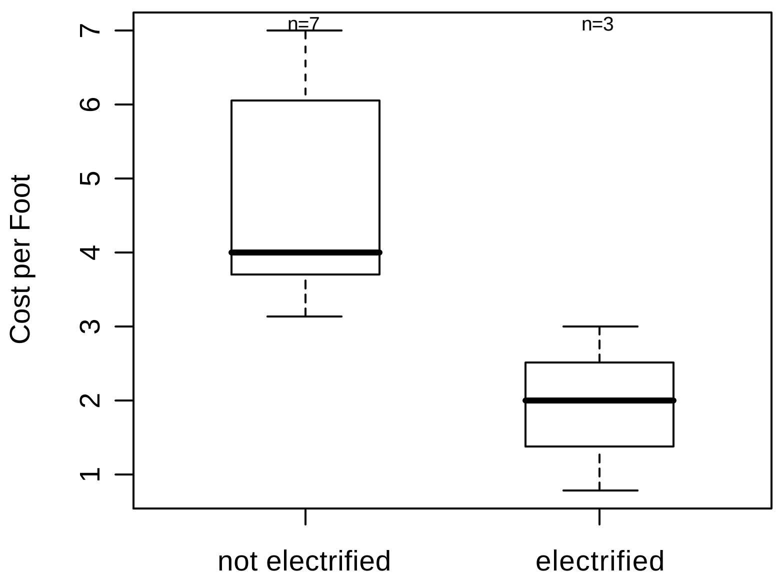

Figure 2. Box plot of cost per foot of fencing for non-electrified and electrified fences.

Site Preparation Difficulty

We did not specifically ask contractors for data on site preparation difficulty. We did ask for site accessibility:

- easy = easy access
- average = partial vehicle access
- difficult = very limited/no vehicle access)

We received data on this variable for 7 of the 11 sites, all of which were classified as easy accessibility.

We also estimated the average slope for each site using Geographical Information Systems (GIS). We calculated slope from U.S. Geological Survey (USGS) 30 meter National Elevation Data (NED) using the Slope function in ArcGIS software (ESRI, 2005). The slope values for all cells intersecting the site were averaged to arrive at an average slope for each site. There was not a significant association between cost per foot of fencing and average slope (Kendal's Tau = 0.30, P = 0.24; Figure 3). Note that all of the electrified fencing projects occurred in areas with low average slopes.

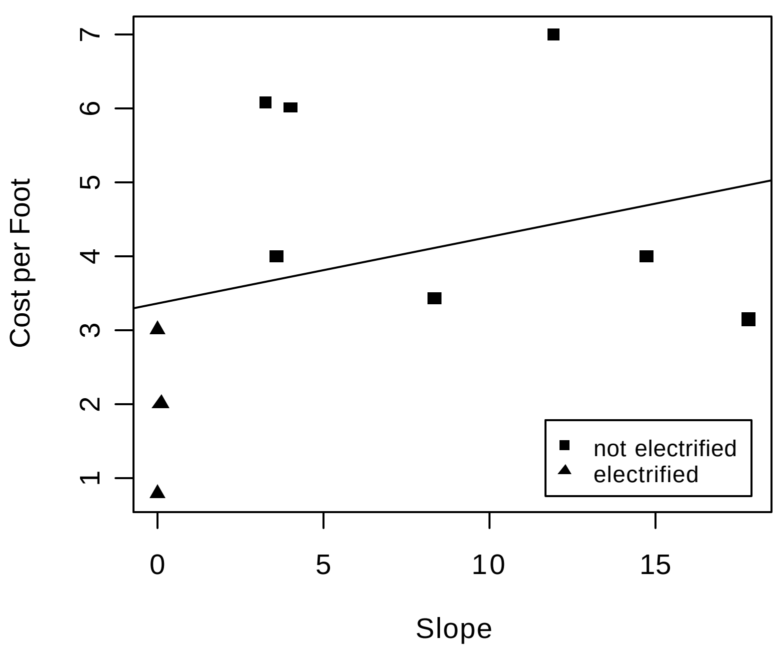

Figure 3. Cost per foot of fencing versus slope. Symbols distinguish electrified fences from ones that are not electrified. Line represents least squares fit.

Labor Cost

Labor costs are a potentially important factor for fencing projects. We did not ask contractors whether labor was provided by volunteers, conservation crew, or contracted employees. We asked restoration contractors whether they were required to pay prevailing wages. This question was asked as a checkbox, which we now realize leads to ambiguous results. Boxes left blank could indicate that prevailing wages were not required or that the question wasn't answered. For this reason, the data on prevailing wages were not reliable. There was not a significant difference in cost between sites where prevailing wages were and were not required (Wilcoxon signed rank test, W = 3, P = 0.23; Figure 4). The prevailing wage data were confounded with fence electrification. Where prevailing wages were required, two of the three sites involved electrified fences, and where prevailing wages were not required, none of the fences were electrified.

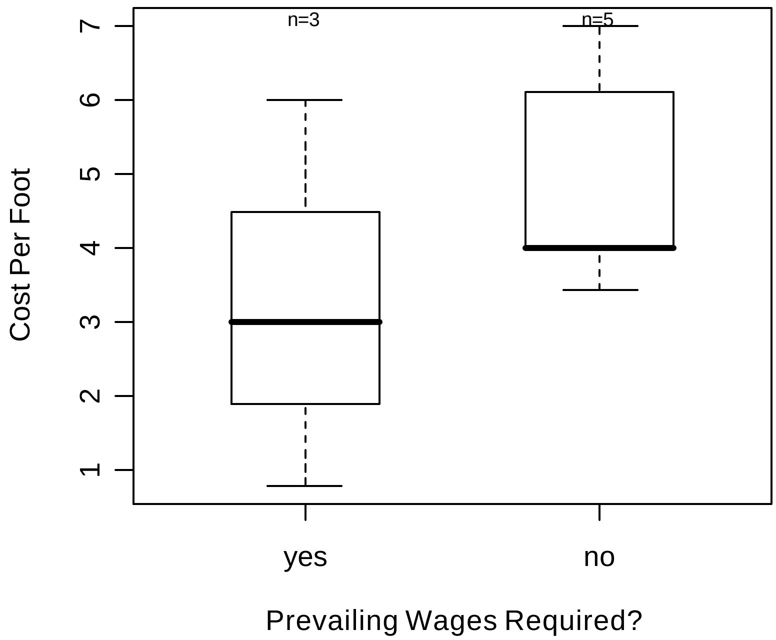

Figure 4. Box plot of cost per foot of fencing for sites where prevailing wages were and were not required.

We also looked at whether cost was associated with county-level average annual construction wages or unemployment rates. Average annual construction wages are for 'Heavy and Civil Engineering Construction' from the Covered Employment and Wages (CEW) program of the Bureau of Labor Statistics. Unemployment rates are county level Labor Force Data from the Labor Market Information Division of the California Employment Development Department. Both types of data were associated with restoration sites by year and geographic location. Some sites are missing construction wage data because data are not available for all counties for each year. There was no association between cost and either variable (Figures 5 and 6).

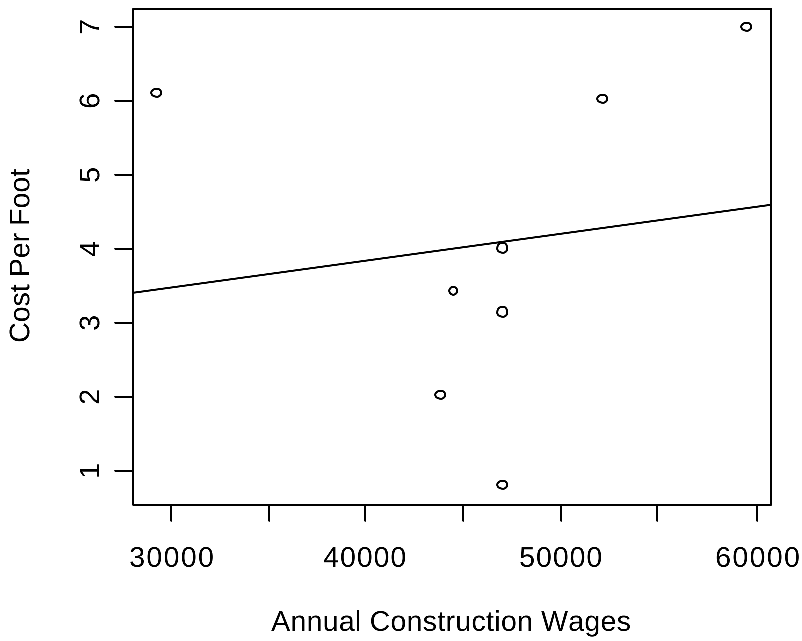

Figure 5. Cost per foot of fencing versus average annual construction wages. Line represents least squares fit.

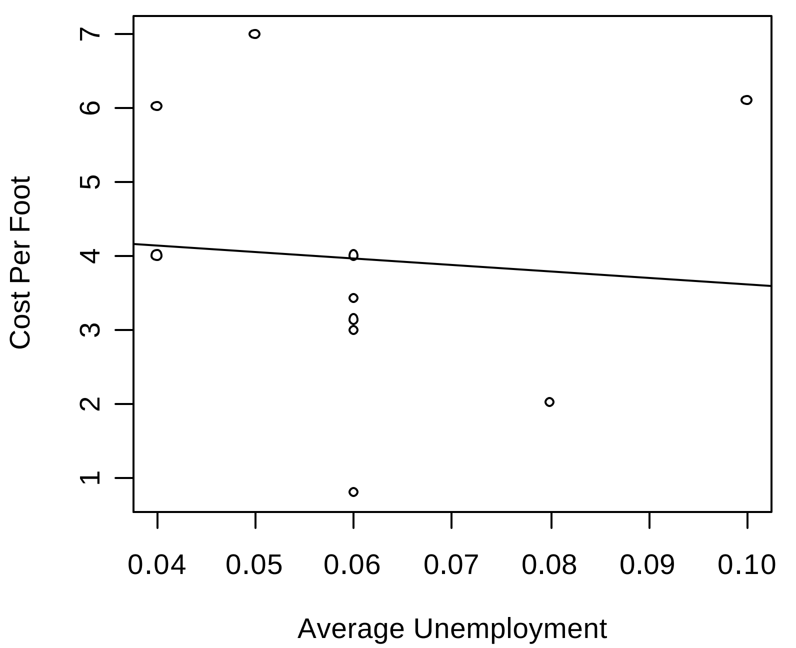

Figure 6. Cost per foot of fencing versus average annual unemployment. Line represents least squares fit.

<u>Fence Analysis Summary</u>

The sample size for fencing projects was very small (10 projects), so we do not have a lot of statistical power for our analyses. The only predictor variable that we looked at that was significantly associated with fencing cost was fencing electrification. Electrified fences on average cost significantly less than fences that were not electrified. There were not significant differences in cost among fences of different complexities, but the trend was as expected – simpler fences cost less on average. The effect of electrification on cost may be confounded with the effect of material complexity, as only fences of simple or average complexity in our sample were electrified; no complex fences were electrified. There were not significant associations between fencing cost and average slope or labor rate variables.

We did not ask contractors to provide information on slope of the site or the amount of clearing needed. These factors are likely to be important to the cost of fencing projects and we recommend that data on these variables be collected in the future. The GIS-derived average slope values that we used in our analyses are likely to be too coarse to accurately reflect the slope at the fencing site.

Riparian Planting

We received data on 42 sites that included cost information associated with riparian planting. The sites came from 32 different projects. There were between 1 and 5 sites per project (Table 16). Number of sites and cost statistics are reported in Tables 17 and 18. Sites in table 18 are a subset of the sites in Table 17 for which we have data on number of trees planted.

Table 16. Number of projects by number of sites per project for riparian planting projects.

Number of Sites	Number of Projects
1	26
2	4
3	1
5	1

Table 17. Summary of riparian planting cost per acre.

Number of Sites	Minimum Cost per Acre	Maximum Cost per Acre	Average Cost per Acre	Standard Deviation of Cost per Acre
42	$40	$434,783	$27,906	72,528

Table 18. Summary of riparian planting cost per tree. Cost per tree is the total riparian planting site cost divided by the number of trees planted as reported by the contractor.

Number of Sites	Minimum Cost per Tree	Maximum Cost per Tree	Average Cost per Tree	Standard Deviation of Cost per Tree
37	$1	$238	$23	48.62

For comparison, we also looked at the cost of riparian planting for projects in the original CHRPD database from 3/14/05 (Table 19). Cost data in the CHRPD are recorded at the project level. To attempt to get accurate values of cost of riparian planting, we limited the projects to those with only one task (riparian planting), one measurement type, and one site per project. We also only looked at projects that began in 1998 or later. None of the selected riparian planting projects from the CHRPD occurs in the new database.

Table 19. Summary of riparian planting cost data from the CHRPD (3/14/05). Sites are limited to projects since 1997 with only one task (riparian planting), one measurement type, and one site per project.

Number of Sites	Unit	Minimum Cost per Unit	Maximum Cost per Unit	Average Cost per Unit	Standard Deviation of Cost per Unit
17	acre	$168	$63,114	$10,855	15,827
10	mile	$3,675	$436,640	$96,049	138,133
7	tree	$1	$587	$110	217
2	student	$265	$866	$566	425

Analysis

As was mentioned above, new data that we collected from contractors included 42 sites with riparian planting data, from 32 different projects. Most statistical analyses require independence of samples, and clearly samples from the same project are not independent. So, for statistical analyses we randomly selected one site from each project and used this subset of the data for our analyses. Cost values are reported here as cost per tree and cost per acre. Cost per tree ranges from $1 to $238 with an average of $ 23. Cost per acre ranges from $40 to $434,783 with an average of $27,906. The cost values are heavily skewed (Figure 7). Analyses were performed on log-transformed cost per acre (Figure 8). The median cost per tree was $4, and the median cost per acre was $2,302.

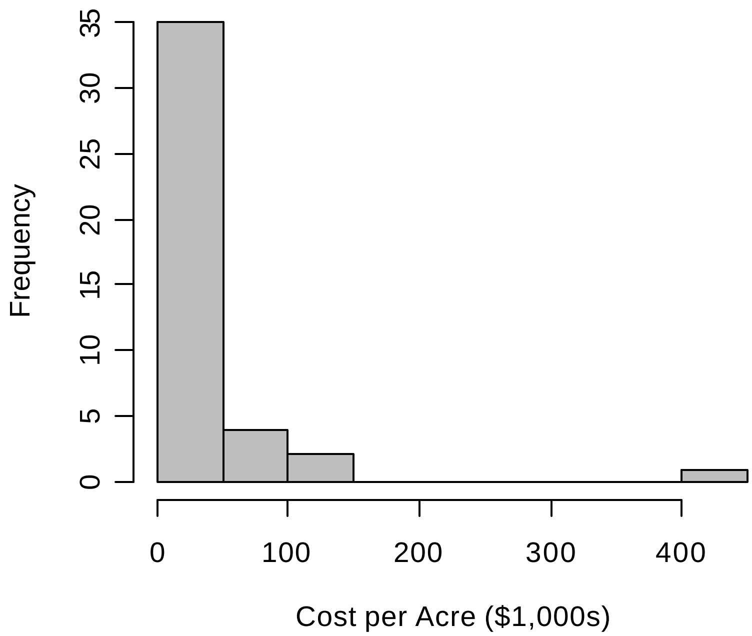

Figure 7. Histogram of cost per acre of riparian planting for the complete dataset.

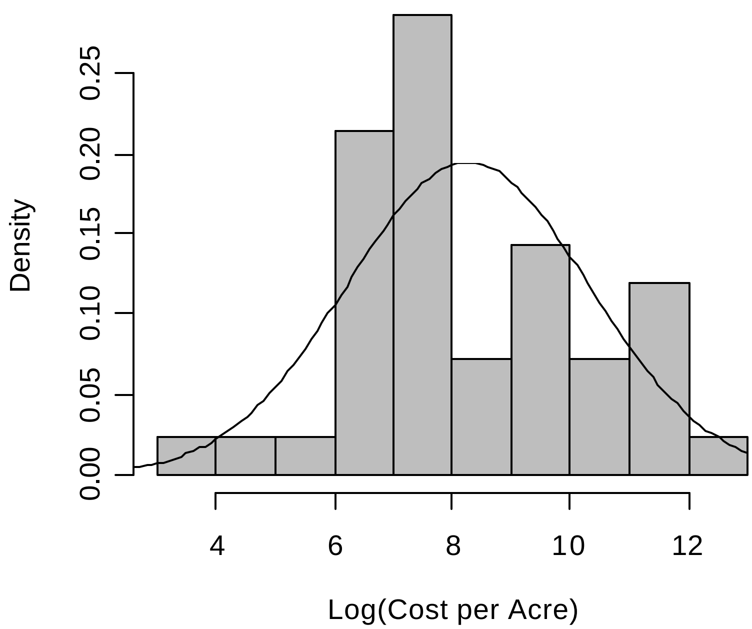

Figure 8. Histogram of log-transformed cost per acre for the complete dataset.

Area Planted

Log transformed cost per acre was significantly associated with the log-transformed number of acres planted (Regression, coef. = -0.61, P = 0.000008, R^2adj = 0.47; Figure 9). Larger projects tend to cost less per acre, indicating that there are some economies of scale with riparian planting projects. A 1% increase in area planted results in a 0.61% decrease in cost per acre.

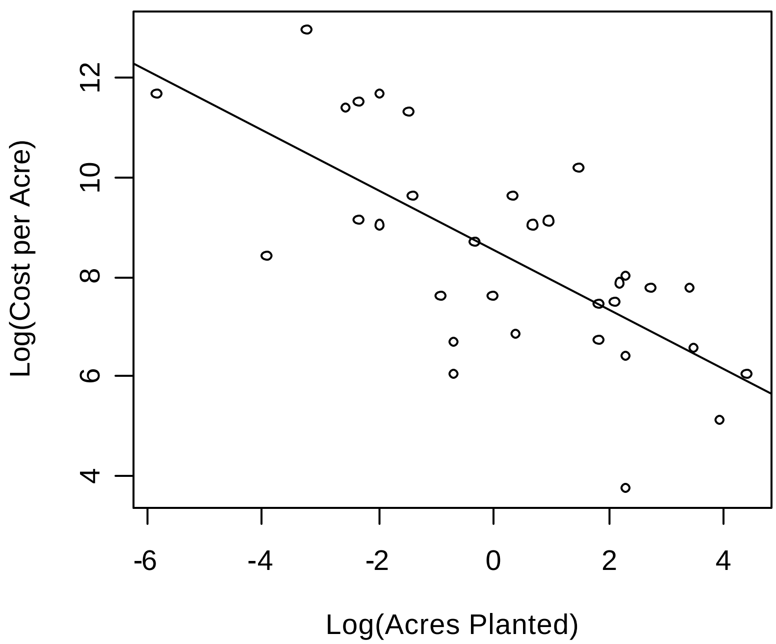

Figure 9. Log(cost per acre) versus log(acres planted) for our sample of one riparian planting site per project.

Site Accessibility

We asked restoration contractors to provide information on site accessibility:

- easy = easy access
- average = partial vehicle access
- difficult = very limited/no vehicle access

We received data on this variable for all 42 of the riparian planting sites. Cost per site and cost per acre are reported in Tables 20 and 21 respectively.

Table 20. Riparian planting cost by site accessibility for the complete dataset.

Site Accessibility	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
easy	18	$100	$23,550	$9,925	8,414	$8,000
average	14	$120	$114,000	$14,809	30,578	$1,400
difficult	10	$500	$87,480	$34,511	29,590	$22,685

Table 21. Riparian planting cost per acre by site accessibility for the complete dataset.

Site Accessibility	Number of Sites	Minimum Cost per Acre	Maximum Cost per Acre	Average Cost per Acre	Standard Deviation of Cost per Acre	Median Cost per Acre
easy	18	$600	$434,783	$55,840	103,910	$8,932
average	14	$40	$87,500	$9,065	23,538	$1,272
difficult	10	$910	$15,109	$4,001	4,541	$2,302

There was a marginally significant difference in log-transformed cost per acre among the different site accessibility classes (Kruskal-Wallis chi-squared = 5.78, df = 2, P = 0.056; Figure 10).

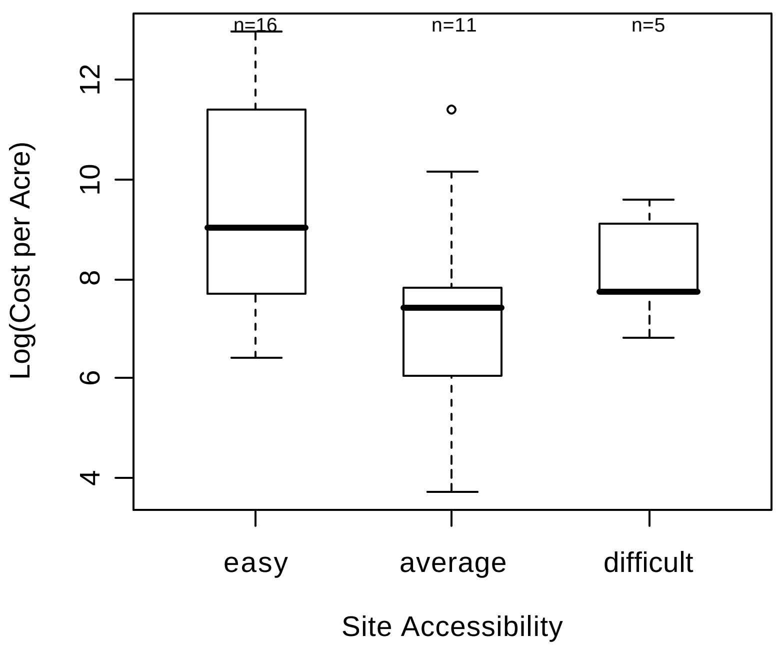

Figure 10. Boxplot of log(cost per acre) for each site accessibility class for our sample of one riparian planting site per project.

There was also a marginally significant difference in log-transformed area planted among the different site accessibility classes (Kruskal-Wallis chi-squared = 4.73, df = 2, p-value = 0.09; Figure 11).

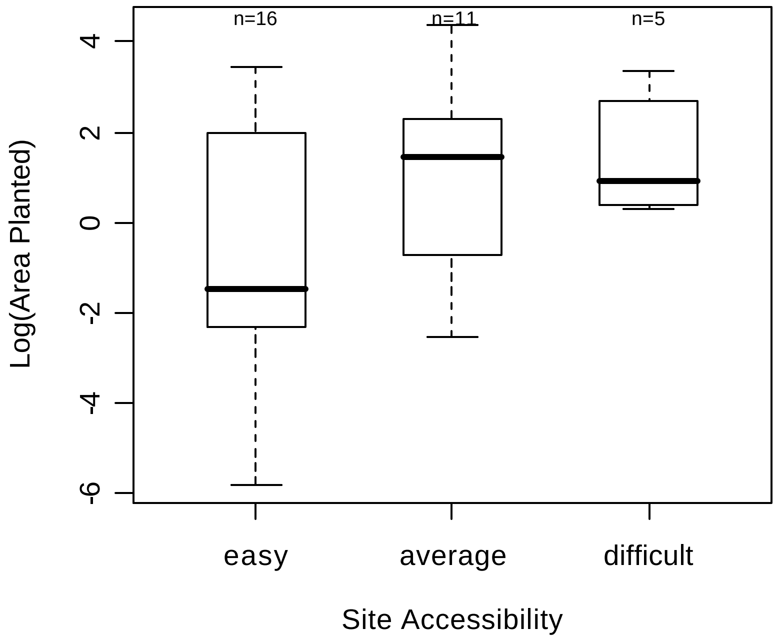

Figure 11. Boxplot of log(area planted) for each site accessibility class for our sample of one riparian planting site per project.

There was not a significant difference in log-transformed cost per acre among site accessibility classes when controlling for the log-transformed number of acres planted (ANCOVA, $R^2 = 0.50$; Table 22)

Table 22. Anova Table (Type II tests), Response: log(Cost per Acre)

	Sum Sq	Df	F value	Pr(>F)
Log(Area Planted)	51.402	1	22.271	5.975e-05
Site Accessibility	8.023	2	1.738	0.1943
Residuals	64.624	28		

Material Cost

We asked restoration contractors to provide information about plant material costs:

- minimal = bare root, native materials readily available, materials donated – in-kind cost not reported.
- moderate = bare root, weed block, landscape fabric, mulch.
- substantial = 1-5+ gallon plants; weed block, landscape fabric/mulch, most materials purchased, native material not readily available or grown from seed).

We received information on material costs for all 42 riparian planting sites. Cost per site and cost per acre are reported in Tables 23 and 24 respectively.

Table 23. Riparian planting cost by material cost for the complete dataset.

Material Cost	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
Minimal	19	$100	$87,480	$20,620	26,481	$10,000
Moderate	15	$120	$22,075	$9,687	8,477	$7,000
Substantial	8	$300	$114,000	$24,250	38,122	$9,074

Table 24. Riparian planting cost per acre by material cost for the complete dataset.

Material Cost	Number of Sites	Minimum Cost per Acre	Maximum Cost per Acre	Average Cost per Acre	Standard Deviation of Cost per Acre	Median Cost per Acre
Minimal	19	$40	$120,000	$14,024	34,069	$2,302
Moderate	15	$120	$434,783	$50,615	113,429	$1,694
Substantial	8	$414	$56,000	$18,294	18,975	$11,521

Log-transformed cost per acre did not differ significantly among the different material cost classes (Kruskal-Wallis chi-squared = 0.44, df = 2, P = 0.80; Figure 12). There was still not a significant association between cost per acre and material cost when controlling for log-transformed area planted.

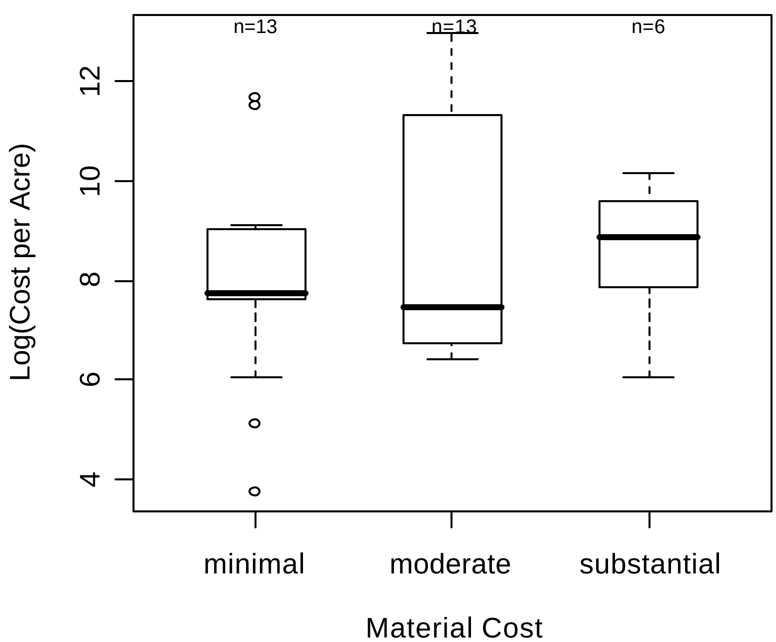

Figure 12. Box plot of log(cost per acre) for material cost categories for our sample of one riparian planting site per project.

Site Preparation Difficulty

We asked restoration contractors to provide information about the difficulty of preparing the site for planting:

- easy = small debris/duff removal, slight sloping
- average = pasture sod removal
- difficult = non-native removal, machine labor
- very difficult = non-native removal, hand labor.

We received data on this variable for 41 of the 42 riparian planting sites. Cost per site and cost per acre are reported in Tables 25 and 26 respectively.

Table 25. Riparian planting cost by site preparation difficulty for the complete dataset.

Site Preparation Difficulty	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
easy	10	$100	$70,000	$9,931	21,953	$1,045
average	13	$200	$30,000	$10,017	9,975	$7,000
difficult	8	$300	$114,000	$25,401	37,444	$15,498
very difficult	10	$120	$87,480	$29,786	26,503	$21,512

Table 26. Riparian planting cost per acre by site preparation difficulty for the complete dataset.

Site Preparation Difficulty	Number of Sites	Minimum Cost per Acre	Maximum Cost per Acre	Average Cost per Acre	Standard Deviation of Cost per Acre	Median Cost per Acre
easy	10	$40	$434,783	$58,729	137,098	$5,054
average	13	$163	$100,000	$17,198	34,313	$2,000
difficult	8	$414	$120,543	$33,324	45,341	$13,837
very difficult	10	$120	$56,000	$9,358	17,002	$2,302

Log-transformed cost per acre did not differ significantly among the different classes of site preparation difficulty (Kruskal-Wallis chi-squared = 0.44, df = 2, P = 0.80; Figure 13).

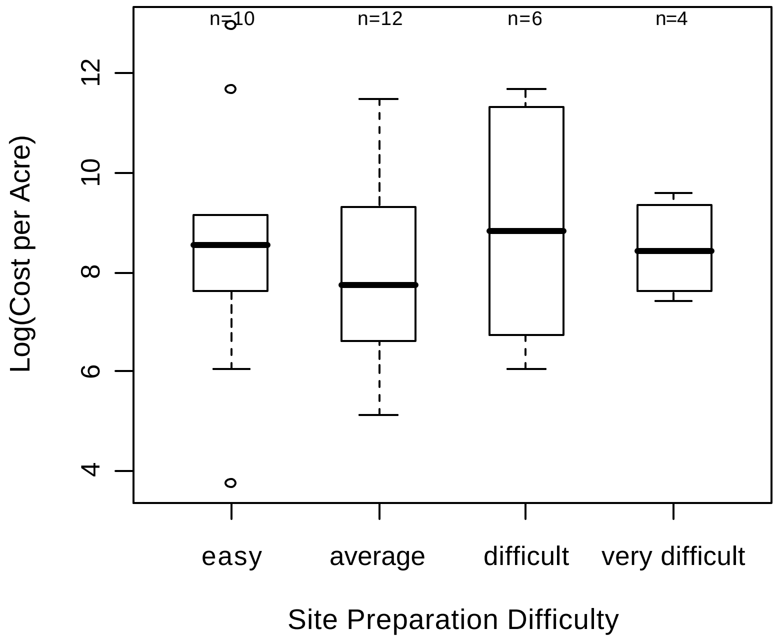

Figure 13. Box plot of log(cost per acre) for site preparation difficulty categories for our sample of one riparian planting site per project.

Area planted appears to increase with site preparation difficulty, although there was not a significant difference in log-transformed area planted among the site preparation difficulty classes (Kruskal-Wallis chi-squared = 4.38, df = 3, P = 0.22; Figure 14). When controlling for area planted, there is a significant effect of site preparation difficulty on log-transformed cost per acre (ANCOVA, R^2 = 0.56; Tables 27 and 28).

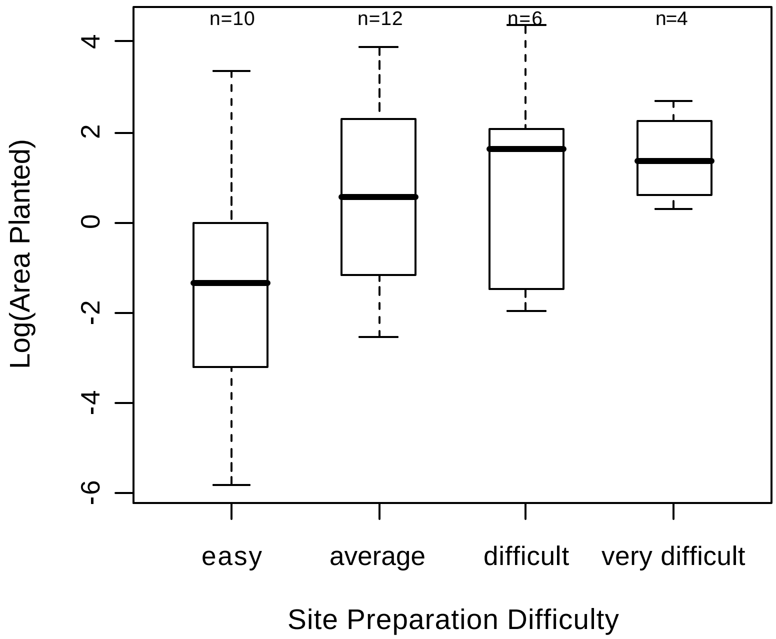

Figure 14. Box plot of log(area planted) for site preparation difficulty categories for our sample of one riparian planting site per project.

Table 27. ANCOVA Table, response = log(cost per acre), overall R^2adj = 0.56, P = 0.000022.

	Estimate	Standard Error	t-value	Pr(>|t|)
(Intercept)	7.5720	0.4720	16.043	2.5e-15
log(Area Planted)	-0.7377	0.1140	-6.470	6.2e-07
Site Preparation: average	0.9314	0.6455	1.443	0.1606
Site Preparation: difficult	2.1073	0.7804	2.700	0.0118
Site Preparation: very difficult	1.9800	0.8964	2.209	0.0359

Table 28. Anova Table (Type II tests), Response: log(Cost per Acre)

	Sum Sq	Df	F value	Pr(>F)
log(Area Planted)	84.709	1	41.8598	6.194e-07
Site Preparation Difficulty	18.009	3	2.9664	0.04969
Residuals	54.639	27		

We also looked at slope as a possible indicator of site preparation difficulty. We estimated the average slope for each site using Geographical Information Systems (GIS). We calculated slope from USGS 30 meter National Elevation Data using the Slope function in ArcGIS software (ESRI, 2005). The slope values for all cells intersecting the site were averaged to arrive at an average slope for each site. There was not a significant effect of slope on log-transformed cost per acre of riparian planting (Regression, P = 0.35, R^2adj = -0.003; Figure 15). There was still not a significant effect of slope when controlling for the number of acres planted.

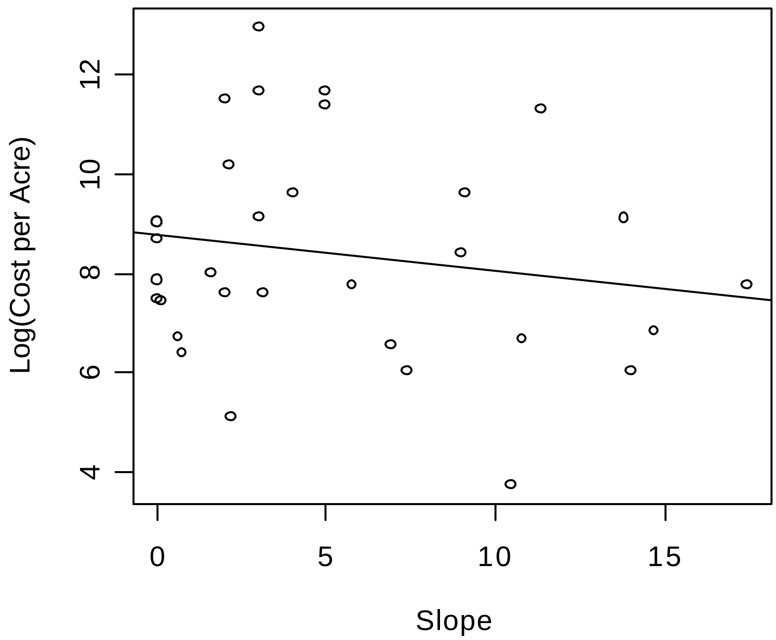

Figure 15. Log-transformed cost per acre of riparian planting versus average slope of the site for our sample of one riparian planting site per project.

Labor Cost

Labor costs are a potentially important factor for riparian planting projects. We did not ask contractors whether labor was provided by volunteers, conservation crew, or contracted employees. We did, however, asked restoration contractors whether they were required to pay prevailing wages (Tables 29 and 30). This question was added to the project form mailed to contractors after the first mailing was sent out, so we do not have data on this variable for most of the projects from the first mailing. In addition, this question was asked as a checkbox, which we now realize leads to ambiguous results. Boxes left blank could indicate that prevailing wages were not required or that the question wasn't answered. For this reason, the data on prevailing wages may not be reliable. For the data we did receive, riparian planting sites where prevailing wages were required had significantly higher log-transformed cost per acre (Wilcoxon signed rank test, W = 100, P = 0.001; Figure 16). The effect of prevailing wages on log-transformed cost per acre remained significant when controlling for the number of acres planted (ANCOVA, P = 0.011, Table 31).

Table 29. Cost of riparian planting for sites where prevailing wages were and were not required for the complete dataset.

Prevailing Wages Required?	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
No	19	$200	$87,480	$20,164	26,855	$6,000
Yes	11	$300	$23,550	$11,282	8,286	$14,000

Table 30. Cost per acre of riparian planting for sites where prevailing wages were and were not required for the complete dataset.

Prevailing Wages Required?	Number of Sites	Minimum Cost per Acre	Maximum Cost per Acre	Average Cost per Acre	Standard Deviation of Cost per Acre	Median Cost per Acre
No	19	$40	$8,500	$1,793	1,818	$2,000
Yes	11	$1,765	$434,783	$77,119	125,433	$32,609

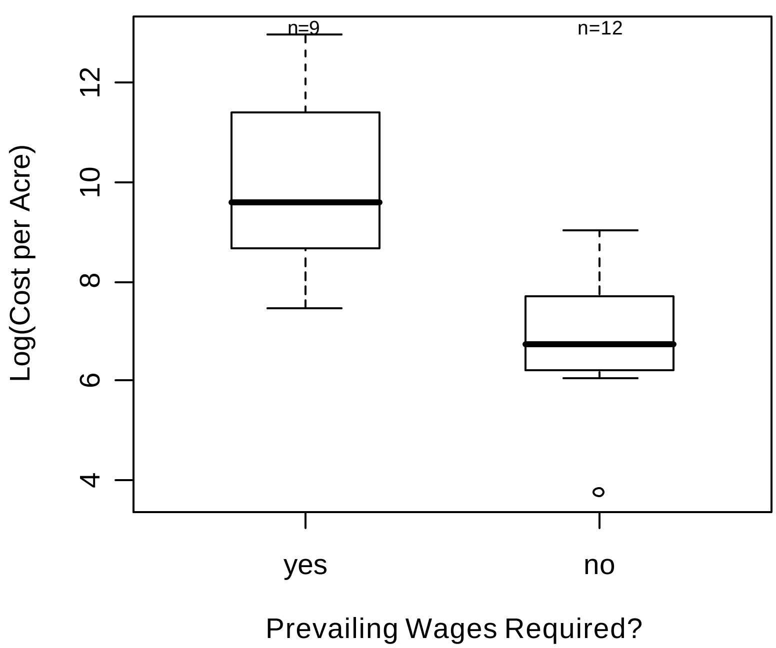

Figure 16. Boxplot of log(cost per acre) for sites where prevailing wages were and were not required for our sample of one riparian planting site per project.

Table 31. ANCOVA Table, response = log(cost per acre), overall R^2adj = 0.62, P = 0.000064.

	Estimate	Standard Error	t-value	Pr(>|t|)
(Intercept)	9.5652	0.4873	19.630	1.33e-13
Prevailing Wages Required: No	-2.0745	0.7300	-2.842	0.0108
log(Area Planted)	-0.4583	0.1678	-2.731	0.0137

We also looked at whether cost was associated with county-level average annual construction wages or unemployment rates. Average annual construction wages are for 'Heavy and Civil Engineering Construction' from the Covered Employment and Wages (CEW) program of the Bureau of Labor Statistics. Unemployment rates are county level Labor Force Data from the Labor Market Information Division of the California Employment Development Department. Both types of data were associated with restoration sites by year and geographic location. Some sites are missing construction wage data because data are not available for all counties for each year.

There was a marginally significant positive association between log-transformed cost per acre and construction wages (Regression, coef. = 1.009e-04, P = 0.097, R^2adj = 0.104; Figure 17). Controlling for area planted, however, the effect of average construction wages was not significant (Regression, P = 0.15).

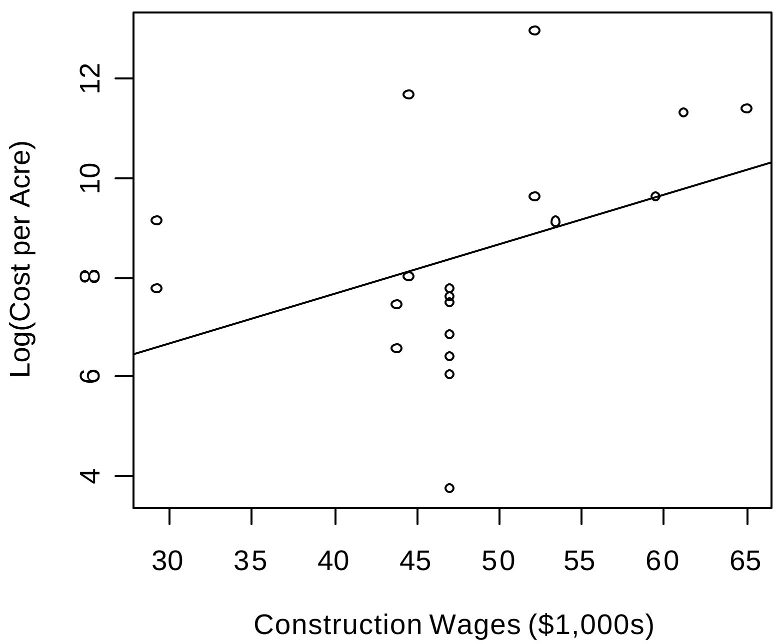

Figure 17. Cost per acre for riparian planting versus average annual construction wages for our sample of one riparian planting site per project. Line represents least squares fit.

There was a significant negative effect of unemployment rate on log-transformed cost per acre (Regression, coef. = -60.30, P = 0.0032, R^2adj = 0.23; Figure 18). Controlling for the log-transformed number of acres planted, the effect of unemployment rate on log-transformed cost per acre of riparian planting remained significant (Regression, coef. = -43.0, P = 0.0051; Table 32). Average construction wages and average unemployment rates are strongly negatively correlated (Figure 19).

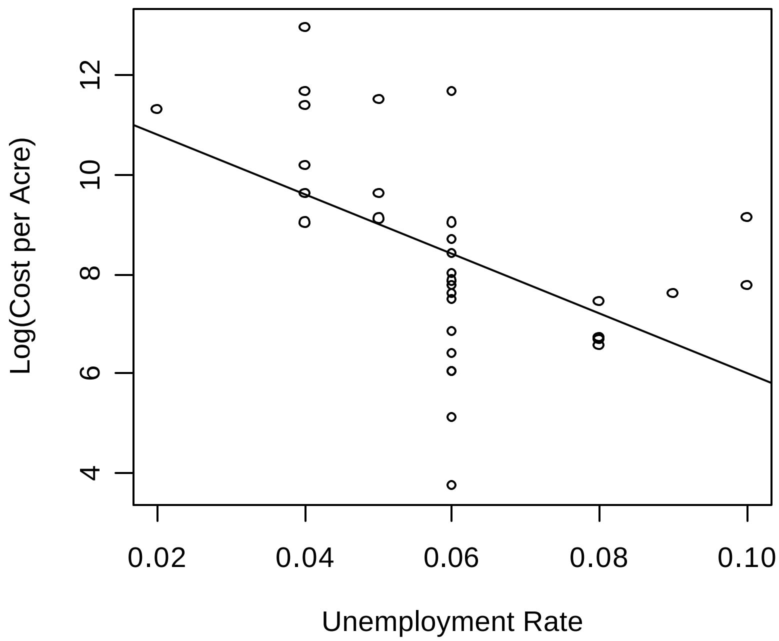

Figure 18. Cost per acre for riparian planting versus average unemployment rate for our sample of one riparian planting site per project. Line represents least squares fit.

Table 32. Regression coefficients, response = log(cost per acre), overall R^2adj = 0.59, P = 0.0000011.

	Estimate	Standard Error	t value	Pr(>|t|)
(Intercept)	11.0970	0.8812	12.592	2.79e-13
Average Unemployment Rate	-42.9729	14.1987	-3.027	0.00515
log(Area Planted)	-0.5332	0.1031	-5.171	1.58e-05

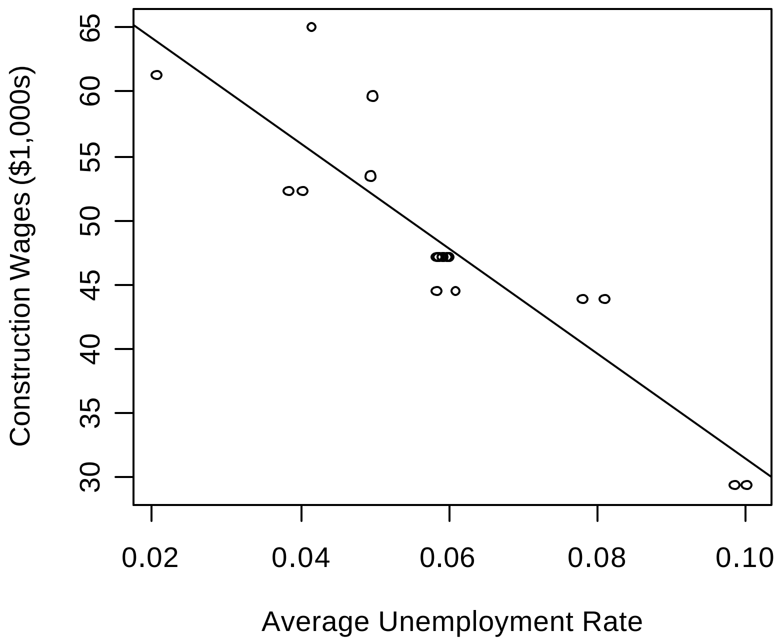

Figure 19. Average annual construction wages versus average unemployment for riparian planting sites for our sample of one riparian planting site per project. Points are offset to show multiple points in the same location.

Irrigation

We asked restoration contractors to provide information about the type of irrigation used: drip irrigation, hand irrigation, or none. Based on the data received, we added a category for DriWater (time release watering system). Tables 33 and 34 summarize the cost information by irrigation type for the complete dataset. Differences in log-transformed cost per acre among irrigation categories were not significant (Kruskal-Wallis chi-squared = 3.59, df = 3, P = 0.31; Figure 20). There was a marginally significant difference in log-transformed cost per acre among irrigation categories when controlling for the log-transformed number of acres planted (Tables 35 and 36).

Table 33. Riparian planting cost by irrigation type for the complete dataset.

Irrigation Type	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
driwater	2	$17,000	$19,249	$18,125	1,590	$18,125
drip irrigation	8	$300	$114,000	$20,288	38,326	$6,137
hand irrigation	8	$5,085	$70,000	$24,808	20,994	$21,614
none	22	$100	$87,480	$15,120	22,592	$4,000

Table 34. Riparian planting cost per acre by irrigation type for the complete dataset.

Irrigation Type	Number of Sites	Minimum Cost per Acre	Maximum Cost per Acre	Average Cost per Acre	Standard Deviation of Cost per Acre	Median Cost per Acre
dri-water	2	$8,500	$83,691	$46,096	53,168	$46,096
drip irrigation	8	$163	$120,543	$33,003	39,655	$20,355
hand irrigation	8	$414	$100,000	$26,232	42,081	$2,667
None	22	$40	$434,783	$27,073	94,483	$2,000

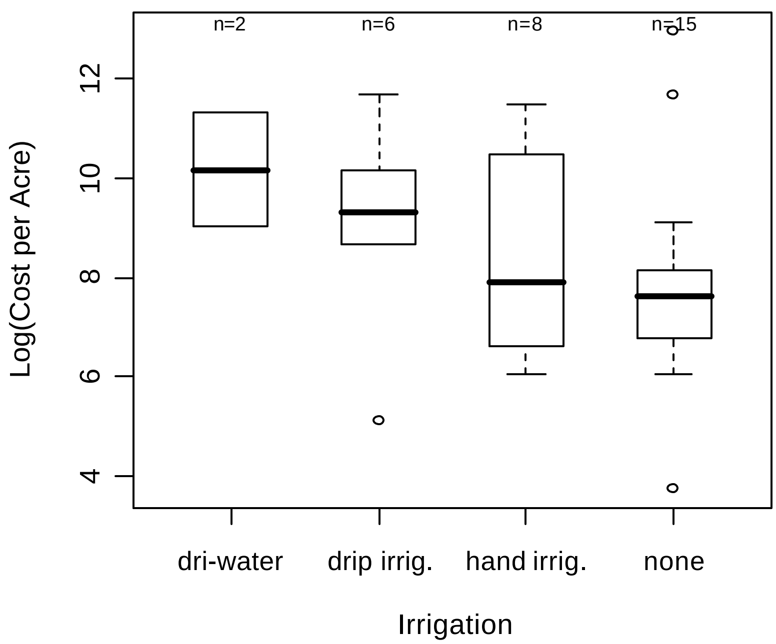

Figure 20. Boxplot of log(cost per acre) for riparian planting sites with different irrigation types for our sample of one riparian planting site per project.

Table 35. ANCOVA Table, response = log(cost per acre), overall R^2adj = 0.56, P = 0.000032.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	9.9354	1.0207	9.734	3.71e-10
Irrigation: drip irrigation	-0.9247	1.1782	-0.785	0.4396
Irrigation: hand irrigation	-0.5955	1.1565	-0.515	0.6109
Irrigation: none	-2.1215	1.0864	-1.953	0.0617
log(Area Planted)	-0.6592	0.1104	-5.971	2.65e-06

Table 36. Anova Table (Type II tests), Response: log(Cost per Acre)

	Sum Squares	Df	F value	Pr(>F)
Irrigation Type	17.901	3	2.8686	0.05575
Log(Area Planted)	74.165	1	35.6546	2.652e-06
Residuals	54.083	26		

Protection

We also asked restoration contractors whether protection was provided for the plants: chemical, tubing, shade protection, or none. Data on this variable was provided for 41 of the 42 riparian planting sites (Table 37). There were not significant differences in log-transformed cost per acre for the different protection categories (Kruskal-Wallis chi-squared = 3.0, df = 4, p-value = 0.56; Figure 21). There were not significant differences in log-transformed cost per acre for projects that used tubing for protection versus those that didn't use any protection (Wilcoxon Rank Sum Test, P = 0.37). There were not significant differences in the area planted for the planting sites with different types of protection (Kruskal-Wallis chi-squared = 4.13, df = 4, p-value = 0.39; Figure 22).

Table 37. Cost per acre of riparian planting by protection type for the complete dataset.

Type of Protection	Number of Sites	Minimum Cost per Acre	Maximum Cost per Acre	Average Cost per Acre	Standard Deviation of Cost per Acre
chemical	1	$2,333	$2,333	$2,333	
shade protection	1	$910	$910	$910	
tubing	16	$120	$120,543	$21,496	35,427
multiple	1	$690	$690	$690	
none	22	$40	$434,783	$37,417	95,457

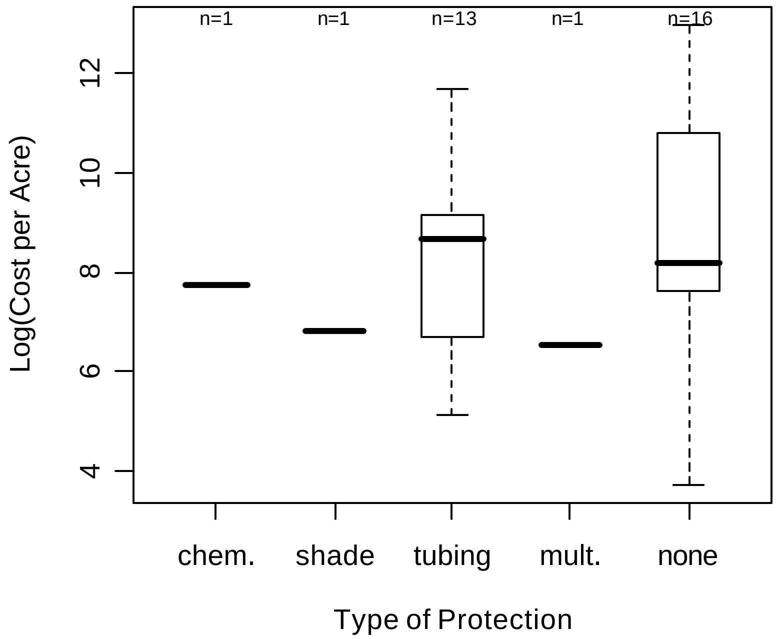

Figure 21. Boxplot of log(cost per acre) for each protection type for our sample of one riparian planting site per project.

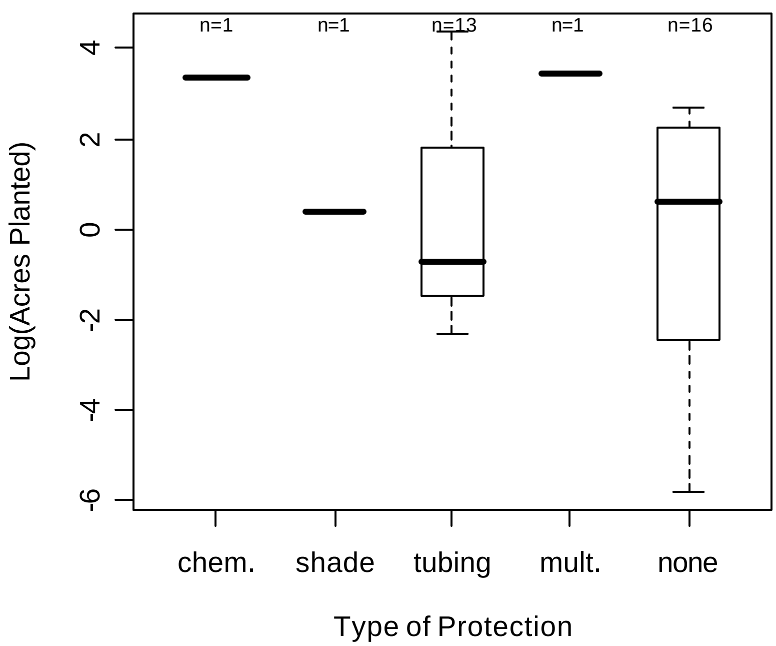

Figure 22. Boxplot of log(acres planted) for each protection type for our sample of one riparian planting site per project.

Precipitation

The amount of local precipitation could affect cost of riparian planting because precipitation affects the need for irrigation, the ease of site preparation, and the ease of plant establishment. We used average annual precipitation data for the climatological period 1961-90 from the Spatial Climate Analysis Service at Oregon State University (SCAS/OSU) to estimate precipitation at each site. The data are in the form of a 1.25 arc-minute resolution spatial grid, which we resampled to a grid cell size of 30.58 meters. The precipitation values for all cells intersecting each site were averaged to arrive at an average precipitation for each site.

There was a significant negative association between log-transformed cost per acre of riparian planting and average annual precipitation (Regression, coef. = 0.077, P = 9.06e-05, R^2adj = 0.39; Figure 23). The effect of precipitation remains significant when controlling for the log-transformed number of acres planted (Regression, coef. = -0.051, P = 0.0017; Table 38).

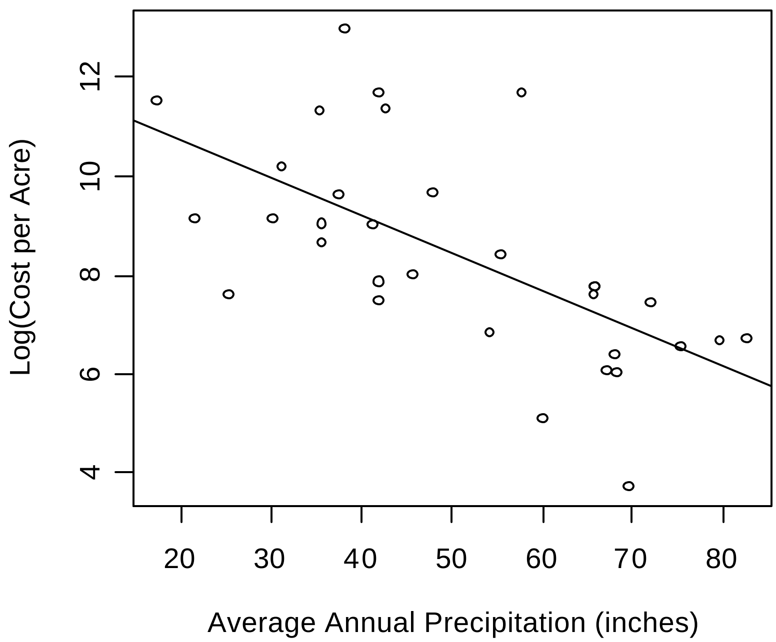

Figure 23. Log(cost per acre) versus average annual precipitation for the climatologic period 1961-1990 (inches) for our sample of one riparian planting site per project.

Table 38. Regression coefficients, response = log(cost per acre), overall R^2adj = 0.61, P = 3.924e-07.

	Estimate	Standard Error	t value	Pr(>|t|)
(Intercept)	11.069	0.77	14.32	1.11e-14
Precipitation (inches)	-0.051	0.015	-3.45	0.0017
log(Area Planted)	-0.46	0.11	-4.33	0.00016

Riparian Planting Analysis Summary

There were significant economies of scale with riparian planting projects. Larger planting projects cost significantly less per acre than smaller projects. The number of acres planted explained 47% of the variability in cost of riparian planting projects. One potential problem with this analysis is that we do not know the percentage of a site that was actually planted, so it is possible that on the larger sites, a smaller fraction of the site was actually planted, resulting in the lower costs per acre.

Controlling for the number of acres planted, there was a significant negative effect of precipitation on cost per acre. Other factors that significantly affected the cost per acre of riparian planting when controlling for number of acres planted included site preparation difficulty and the type of irrigation that was used (marginally significant). In addition, sites where contractors were required to pay prevailing wages for labor had significantly higher costs per acre than sites where prevailing wages were not required, and sites in areas with higher average unemployment rates cost less per acre of planting on average than sites with lower average unemployment rates. In theory, it would be easier to find cheap labor in areas with higher average unemployment rates.

Culvert Replacement

We received data on 42 sites that included cost information associated with culvert replacement. The sites came from 31 different projects. There were between 1 and 5 sites per project (Table 39). Number of sites and cost statistics are reported in Table 40.

Table 39. Number of projects by number of sites per project for culvert replacement projects

Number of Sites	Number of Projects
1	24
2	5
3	1
5	1

Table 40. Summary of culvert replacement cost.

Number of Sites	Minimum Cost per Culvert	Maximum Cost per Culvert	Average Cost per Culvert	Standard Deviation of Cost per Culvert
42	$379	$420,393	$95,986	133,981

For comparison, we also looked at the cost of culvert replacement for projects in the original CHRPD database from 3/14/05 (Table 41). Cost data in the CHRPD are recorded at the project level. To attempt to get accurate values of cost of culvert replacement, we limited the projects to those with only one task (culvert replacement), one measurement type, and one site per project. We also only looked at projects that began in 1998 or later. Only six projects met these criteria. One of the selected culvert replacement projects from the CHRPD (ProjID 704823) occurs in the new database, but this project involved the replacement of a bridge, not a culvert, and so was not included in the culvert replacement analysis.

Table 41. Summary of culvert replacement cost data from the CHRPD (3/14/05). Sites are limited to projects since 1997 with only one task (culvert replacement), one measurement type, and one site per project. The high cost project with units of 'crossing' is a bridge replacement project, not a culvert replacement.

Number of Sites	Unit	Minimum Cost per Unit	Maximum Cost per Unit	Average Cost per Unit	Standard Deviation of Cost per Unit
3	culvert	$1,924	$24,234	$13,339	11,164
2	crossing	$22,684	$500,000	$261,342	337,513
1	structure	$5,631	$5,631	$5,631	

Analysis

As was mentioned above, new data that we collected from contractors included 42 sites with culvert replacement data, from 31 different projects. Most statistical analyses require independence of samples, and clearly samples from the same project are not independent. So, for statistical analyses we randomly selected one site from each project and used this subset of the data for our analyses. Cost values are reported here as cost per culvert. 39 of the sites have a single culvert replacement, 2 have 2 culvert replacements, and one has 12 culvert replacements. Cost per culvert ranged from $378.50 to $420,393.50 with an average of $95,986.40. Values of cost per culvert are heavily skewed and somewhat multi-modal (Figure 24). The median cost per culvert is $15,763. Analyses were performed on log-transformed cost per culvert (Figure 25). Note the bimodal distribution of the log-transformed data.

There is considerable missing data for the various predictor variables for culvert replacement. Before randomly sampling one site from each project, we limited the data to the subset of sites that have data for road type, stream flow, and excavation amount. There were 33 sites in this subset from 25 projects.

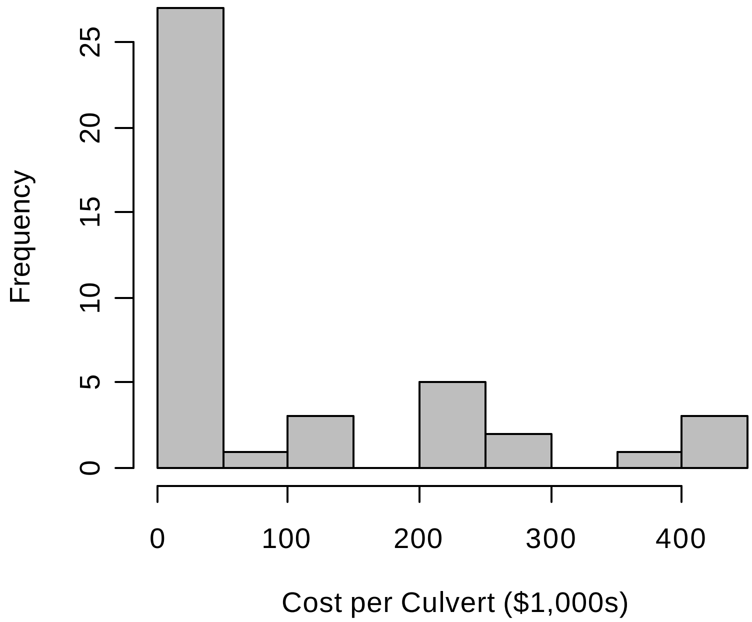

Figure 24. Histogram of cost per culvert for all culvert replacement projects.

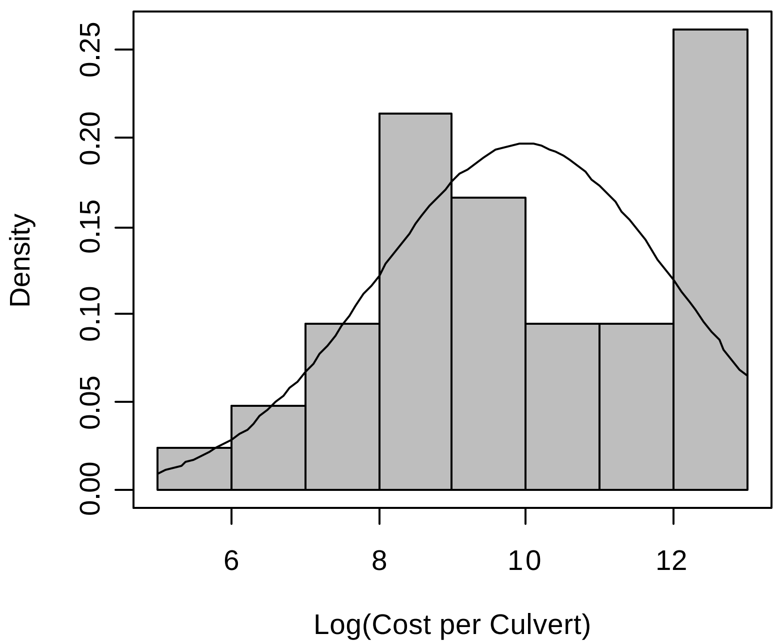

Figure 25. Probability density of log-transformed cost per culvert for all culvert replacement projects.

Road Type

We asked restoration contractors to provide the type of road above the culvert: forest road, minor 2 lane, major 2 lane, or highway 4+ lane. Of the 42 sites for which culvert replacement data were collected, 27 were forest roads, 13 were minor 2 lane, 1 was a major 2 lane, and 1 had no data for road type; there were no culvert replacements associated with highways in our dataset (Table 42). For our analysis of cost by road type, we eliminated the major 2 lane road category because it only had one data point. For our sample of sites, log-transformed cost per culvert was significantly higher for minor 2 lane roads than for forest roads (Wilcoxon rank sum test,W = 8, P = 4.96e-05; Figure 26).

Table 42. Cost per culvert of culvert replacement by road type for the complete dataset.

RoadType	Number of Sites	Minimum Cost per Culvert	Maximum Cost per Culvert	Average Cost per Culvert	Standard Deviation of Cost per Culvert	Median Cost per culvert
forest road	27	$379	$217,907	$23,391	47,311	$7,700
minor 2 lane	13	$5,075	$412,781	$227,113	129,735	$224,212
major 2 lane	1	$420,393	$420,393	$420,393		$420,394

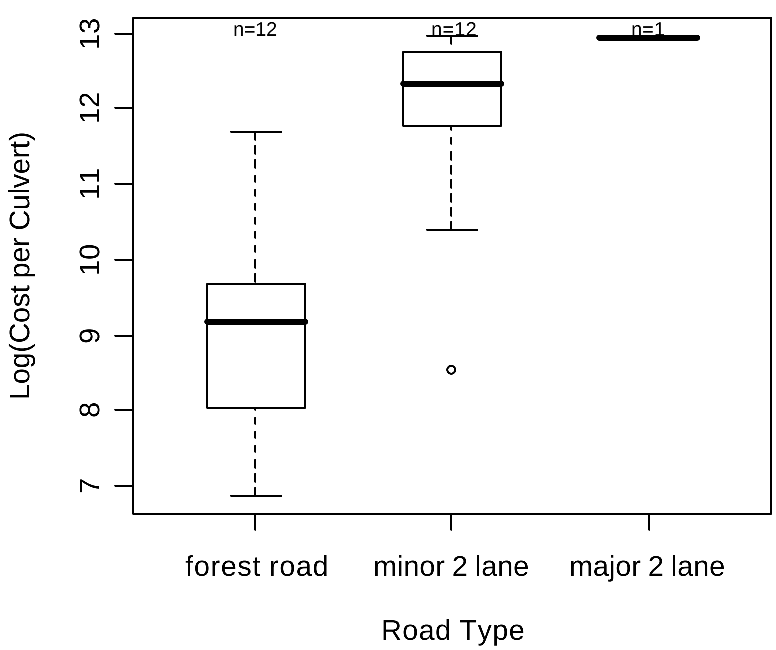

Figure 26. Boxplot of log(cost per culvert) for culvert replacement sites with different road types for our sample of one culvert replacement site per project.

Stream Characteristics

We asked restoration contractors to provide information on stream order as a surrogate for stream size: 1st order, 2nd order, or 3rd order and above. Of the 42 bank stabilization projects, 30 have stream orders provided by contractors. Stream order values provided by contractors were double-checked against routed hydrography data from the California Department of Fish and Game (CDFG). Of the 30 stream orders reported by contractors for culvert replacement sites, 18 (60%) were incorrect according to the CDFG stream data. These values were corrected (1 was higher than reported and 17 were lower). 9 additional sites, for which contractors did not provide stream order, were assigned stream orders based on the CDFG hydrography data (7 sites) or the DEM derived hydrography data (2 sites), resulting in 39 sites with stream orders. Of the 39 sites with stream order data, 30 were on first order streams, 8 on 2nd order, and 1 on 3rd order and above. Cost per site and cost per culvert are reported in Tables 43 and 44 respectively.

Table 43. Cost of culvert replacement by stream order for the complete dataset.

Stream Order	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
1st order	30	$1,479	$420,393	$70,436	118,441	$9,675
2nd order	8	$10,210	$412,781	$176,535	$164,279	$131,288
3rd order and above	1	$285,530	$285,530	$285,530		$285,530

Table 44. Cost per culvert of culvert replacement by stream order for the complete dataset.

Stream Order	Number of Sites	Minimum Cost per Culvert	Maximum Cost per Culvert	Average Cost per Culvert	Standard Deviation of Cost per Culvert	Median Cost per Culvert
1st order	30	$970	$420,393	$70,404	118,460	$9,675
2nd order	8	$851	$412,781	$175,365	165,660	$131,288
3rd order and above	1	$285,530	$285,530	$285,530		$285,530

Cost of culvert replacement was significantly higher for sites on 2nd order streams than for sites on 1st order streams (Wilcoxon signed rank test, W = 22, P = 0.033; Figure 27).

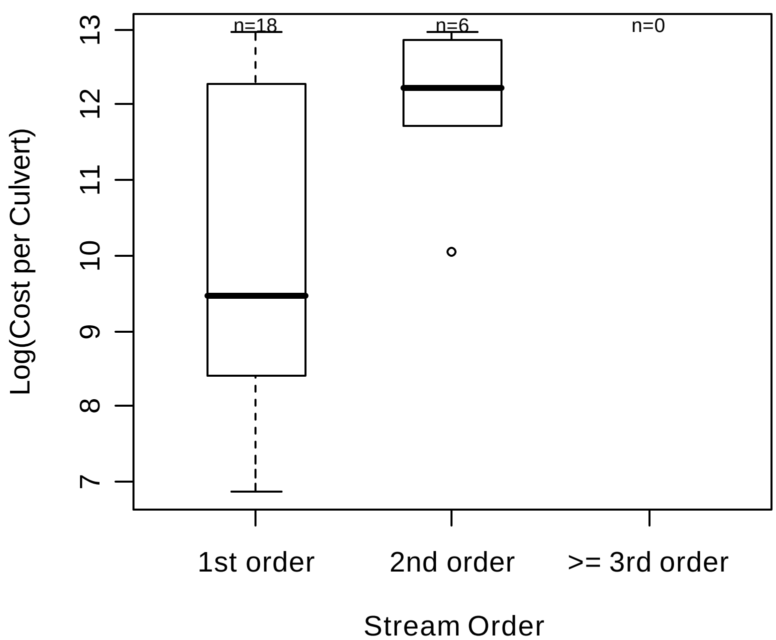

Figure 27. Boxplot of log(cost per culvert) by stream order for our sample of one culvert replacement site per project.

Estimates of actual stream flow were derived using a program that estimates stream characteristics based on topography and rainfall (Miller, 2003). Sites were associated with streams output by this program in a GIS system based on proximity, and the flow for the reach that corresponded to the center of the site was recorded. Using this methodology, flow values could be estimated for 36 of the 42 instream sites. The remaining sites could not be unambiguously assigned to a stream in the DEM-derived hydrography. There was one outlier with very high flow in the stream flow data. This site was also the only culvert replacement on a 3rd order stream. Examination of the notes for this site (7200476) revealed that the culvert is not in the stream but adjacent to it where excess water flows when flows are high, so the stream characteristics for this data point do not accurately relate to the culvert replacement data. This point was omitted from the analyses of stream characteristics.

Flow estimates were heavily right skewed (Figure 28). Log-transformed cost per culvert was significantly positively associated with log-transformed flow (Regression, coef = 0.70, P = 2.27e-06, R^2adj = 0.63; Figure 29). As would be expected, stream flow differs significantly for the different stream orders (Wilcoxon signed rank test, W = 24, p-value = 0.049; Figure 30).

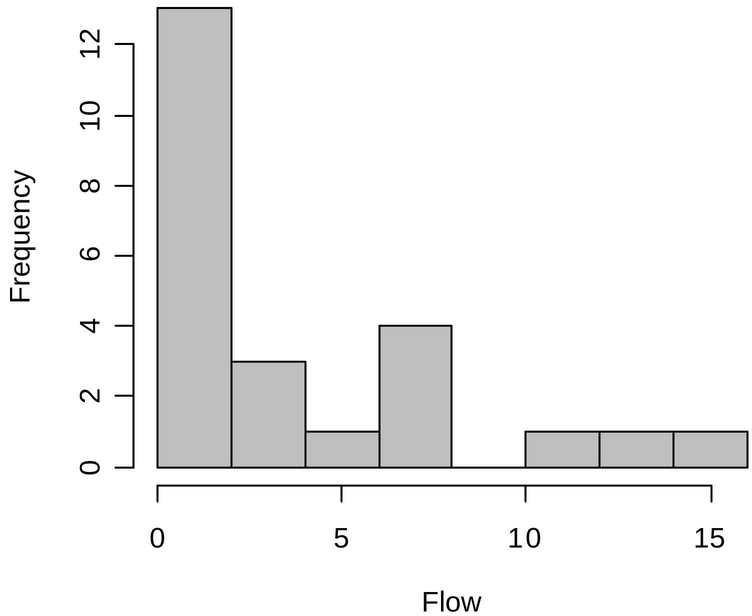

Figure 28. Histogram of stream flow.

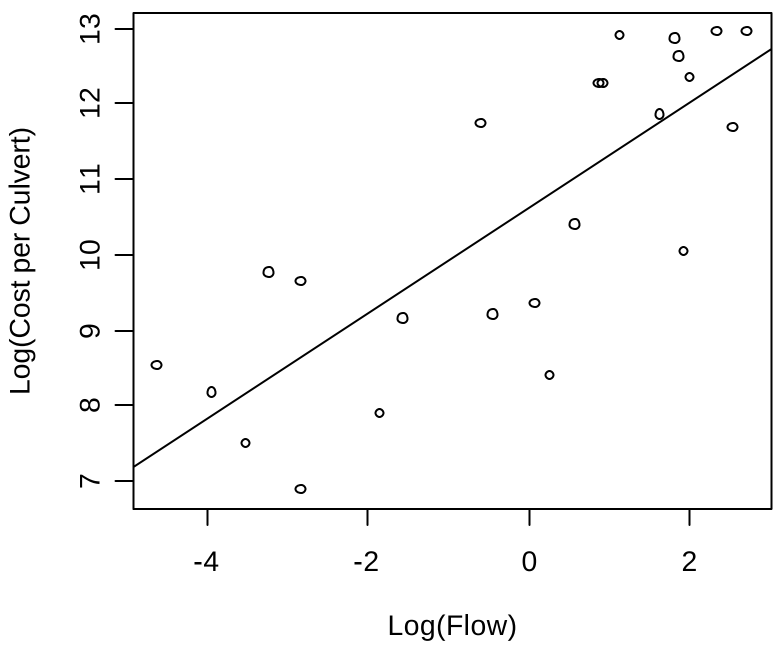

Figure 29. Log(cost per culvert) versus log(stream flow) for our sample of one culvert replacement site per project. Line represents least squares fit. Flow values are measured in cubic feet per second.

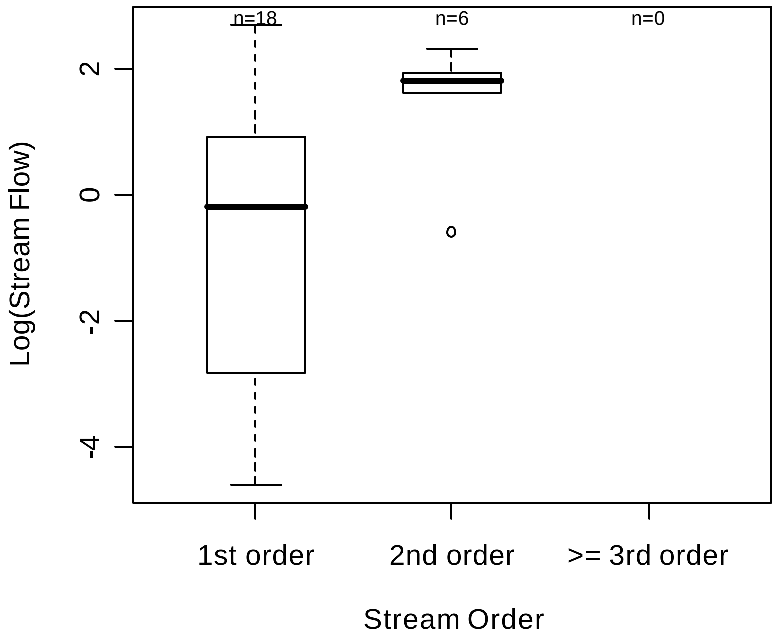

Figure 30. Boxplot of log(stream flow) for each stream order. Flow values are measured in cubic feet per second.

Flow was also associated with road type. The flow under minor 2-lane roads was significantly higher than that under forest roads (Wilcoxon signed rank test, $W = 33$, $P = 0.045$; Figure 31).

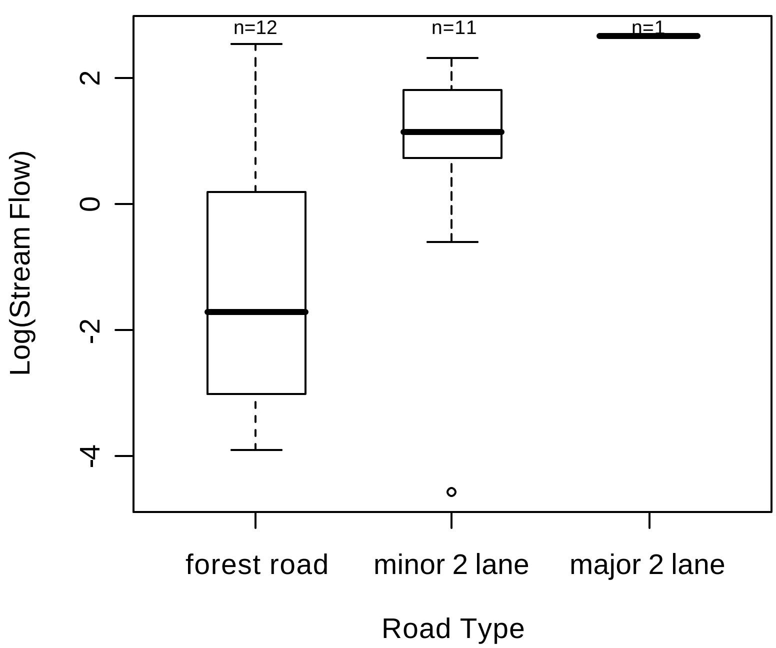

Figure 31. Boxplot of log(stream flow) for each road type. Flow values are measured in cubic feet per second.

Culvert Characteristics

We asked restoration contractors to provide the diameter (in inches) and length (feet) of the replacement culvert. We also asked for the type of the replacement culvert – corrugated steel pipe, structural steel pipe (SSP) open bottom arch, open-bottom concrete box/arch, closed concrete box, concrete circular or arch pipe, log/wood, or bridge – and whether the culvert was constructed onsite or was precast. Diameters were provided for 32 and lengths for 41 of the 42 culvert replacement projects. We received information about the type of culvert for all but one of the culvert replacement sites (Table 45 and 46), and about the construction of the culvert for all but one of the culvert replacement sites (Tables 47 and 48).

Table 45. Cost of culvert replacement by culvert type for the complete dataset. The 'other' category represents types that were not included in the choices but were written in by the contractor. 5 of the 6 culverts in the 'other' category were plastic pipe culverts.

Culvert Type	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
bridge	9	$23,018	$420,393	$162,688	167,588	$23,018
corrugated steel pipe	17	$757	$15,356	$5,481	4,030	$757
open-bottom concrete box/arch	1	$376,696	$376,696	$376,696		$376,696
other	6	$3,500	$138,577	$32,186	52,425	$3,500
SSP open bottom arch	8	$124,000	$401,078	$238,093	79,212	$124,000

Table 46. Cost per culvert for culvert replacement by culvert type for the complete dataset. The 'other' category represents types that were not included in the choices but were written in by the contractor. 5 of the 6 culverts in the 'other' category were plastic pipe culverts.

Culvert Type	Number of Sites	Minimum Cost per Culvert	Maximum Cost per Culvert	Average Cost per Culvert	Standard Deviation of Cost per Culvert	Median Cost per Culvert
bridge	9	$23,018	$420,393	$162,688	167,588	$ 87,000
corrugated steel pipe	17	$379	$15,356	$5,401	4,117	$ 4,500
open-bottom concrete box/arch	1	$376,696	$376,696	$376,696		$ 376,696
other	6	$3,500	$138,577	$32,186	52,425	$ 14,373
SSP open bottom arch	8	$124,000	$401,078	$238,093	79,212	$ 221,060

Table 47. Cost of culvert replacement for culverts that were precast or constructed onsite for the entire dataset.

Const	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
onsite	19	$1,800	$412,781	$140,334	135,724	$124,000
precast	22	$757	$420,393	$62,019	125,840	$6,900

Table 48. Cost per culvert of culvert replacement for culverts that were precast or constructed onsite for the entire dataset.

Const	Number of Sites	Minimum Cost per Culvert	Maximum Cost per Culvert	Average Cost per Culvert	Standard Deviation of Cost per Culvert	Median Cost per Culvert
onsite	19	$1,800	$412,781	$140,334	135,724	$124,000
precast	22	$379	$420,393	$61,532	126,070	$5,555

There was a highly significant positive relationship between log-transformed cost per culvert and log-transformed culvert diameter (Regression, coef. = 2.0, P = 1.38e-08, R^2adj = 0.85; Figure 32). Open-bottom arch culverts tended to have higher cost and larger diameters than corrugated steel pipe culverts (Figure 32). Log-transformed culvert diameter was significantly dependent on log-transformed stream flow (Regression, coef = 0.39, P = 2.06e-06, R^2adj = 0.75) and was also significantly associated with the type of road above the culvert – minor 2 lane roads were associated with larger culverts than forest roads.

Log-transformed cost per culvert was also significantly positively associated with culvert length (Regression, coef. = 0.033, P = 0.041, R^2adj = 0.13; Figure 33).

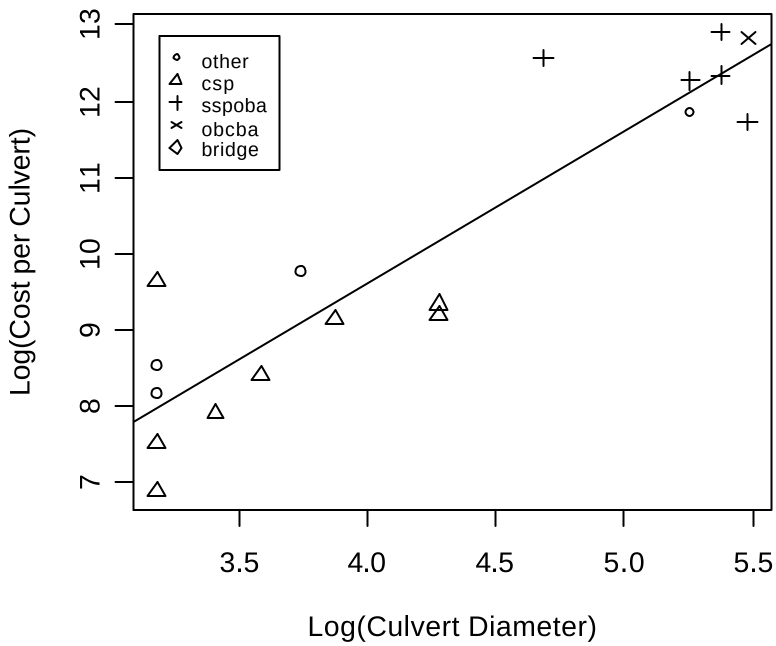

Figure 32. Log(cost per culvert) versus log(culvert diameter) for our sample of one culvert replacement site per project. Line represents least squares fit. Diameter is measured in inches. Culvert types are distinguished by symbols: csp = corrugated steel pipe, sspoba = structural steel pipe open bottom arch, obcba = open bottom concrete box arch.

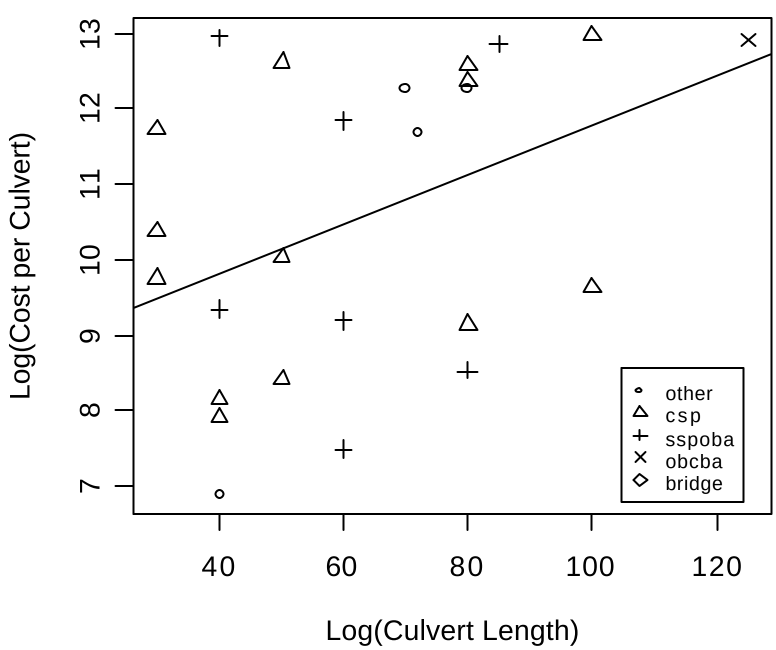

Figure 33. Log(cost per culvert) versus culvert length for our sample of one culvert replacement site per project. Line represents least squares fit. Length is measured in feet. Culvert types are distinguished by symbols: csp = corrugated steel pipe, sspoba = structural steel pipe open bottom arch, obcba = open bottom concrete box arch.

There were significant differences in cost among the different culvert types (Kruskal-Wallis chi-squared = 17.08, df = 4, P = 0.0019; Figure 34). There was not a significant difference in cost between corrugated steel pipe (csp) culverts and those in the 'other' category, most of which are plastic pipe culverts (Wilcoxon signed rank test, W = 23, p-value = 0.28). We reclassified the culvert types to group plastic pipe culverts from the 'other' category and the csp culverts into a pipe culvert category (p) and group open bottom concrete box arch culverts (obcba) with structural steel pipe open bottom arch culverts (sspoba) into an open bottom arch category (oba) (Figure 35 and Table 49).

Log-transformed cost per culvert was higher for bridges and open bottom arch culverts than for pipe culverts (ANOVA, P = 2.831e-08, Tukey Padj < 0.00001; Figure 35). Stream flow also differed significantly among the different culvert types. As would be expected, bridges and open-bottom arch culverts tended to be on higher flow streams than pipe culverts (Tukey, Padj <0.001; Figure 36).

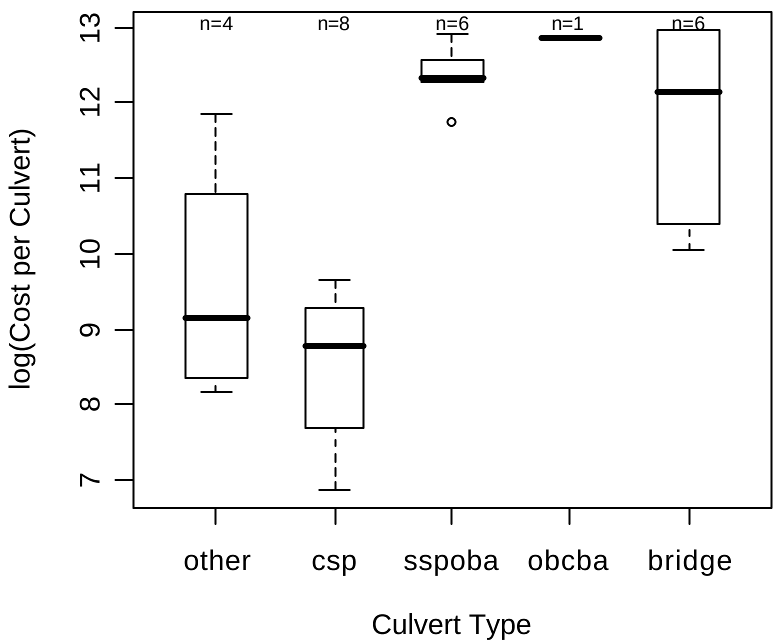

Figure 34. Boxplot of log(cost per culvert) for each culvert type for our sample of one culvert replacement site per project. csp = corrugated steel pipe, sspoba = structural steel pipe open bottom arch, obcba = open bottom concrete box arch.

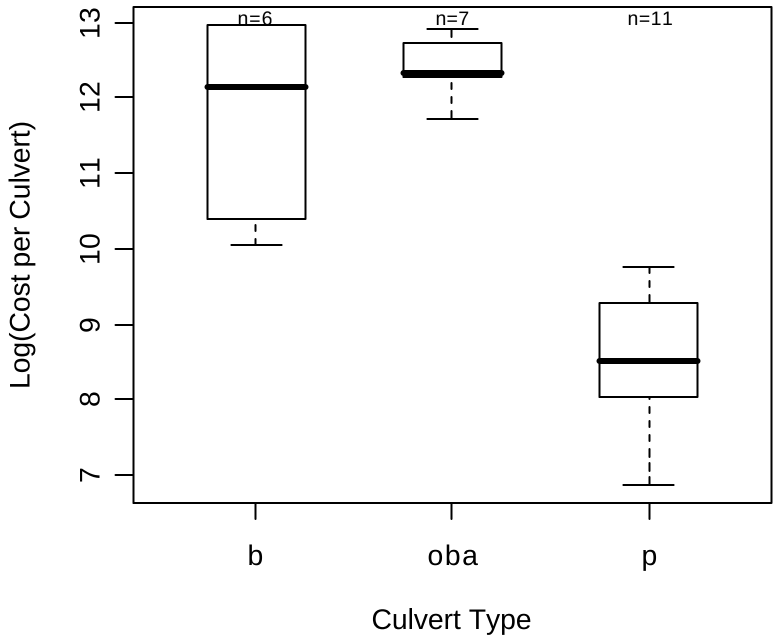

Figure 35. Boxplot of log(cost per culvert) for each culvert type for our sample of one culvert replacement site per project. b = bridge, oba = open-bottom arch, p = pipe.

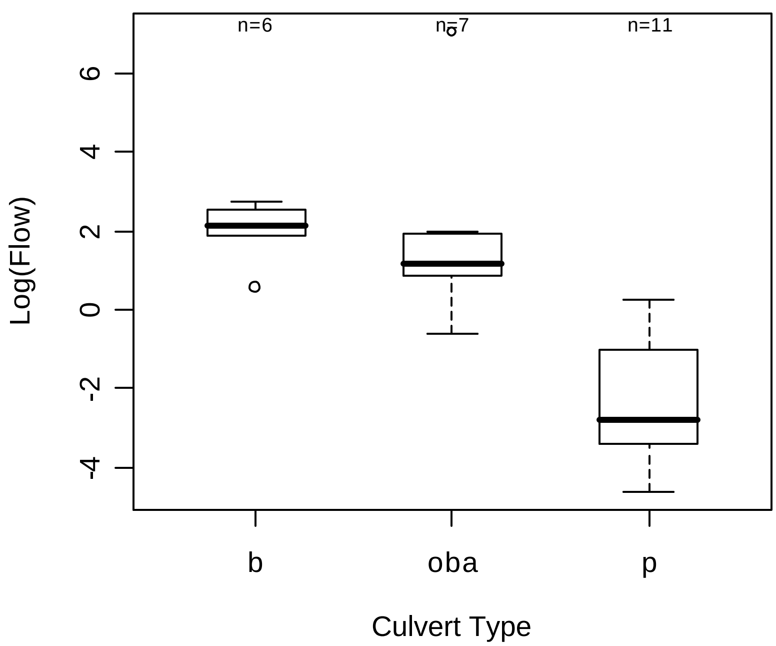

Figure 36. Boxplot of log(flow) for each culvert type for our sample of one culvert replacement site per project. b = bridge, oba = open-bottom arch, p = pipe.

Table 49. Cost per culvert by culvert type for our sample of one culvert replacement site for each project.

Culvert Type	Number of Sites	Minimum Cost per Culvert	Maximum Cost per Culvert	Average Cost per Culvert	Standard Deviation of Cost per Culvert	Median Cost per Culvert
bridge	6	$23,018	$420,393	$217,866	183,278	$209,250
open-bottom arch	7	$124,000	$401,078	$262,760	98,550	$228,775
pipe	11	$970	$17,218	$7,440	5,565	$5,075

Overall, there was no difference in log-transformed cost per culvert for sites with precast culverts compared with sites where culverts were constructed onsite (Figure 37). Separating out the culvert types, there appear to be differences within some types (Figure 38). For example, bridges constructed onsite appear to cost more than precast bridges, but the sample sizes are too small for statistical analyses.

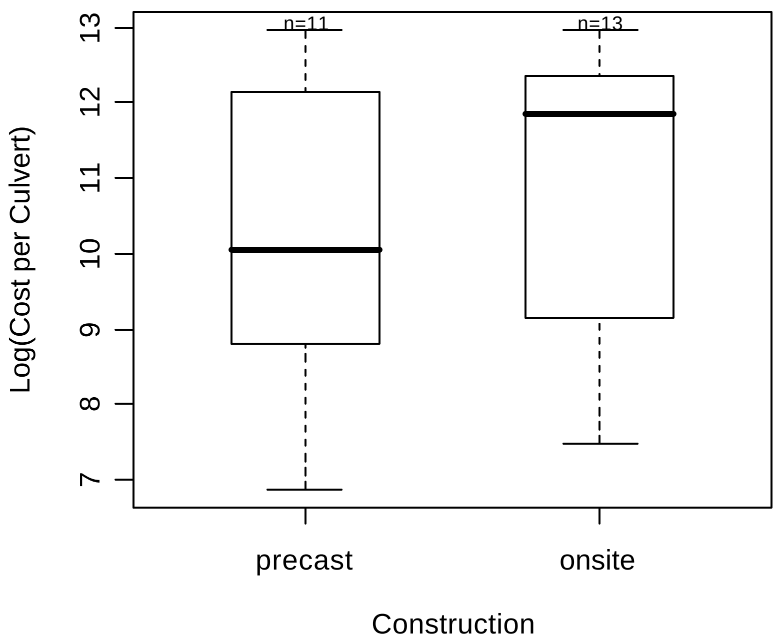

Figure 37. Boxplot of log(cost per culvert) for projects with precast culverts and culverts constructed onsite.

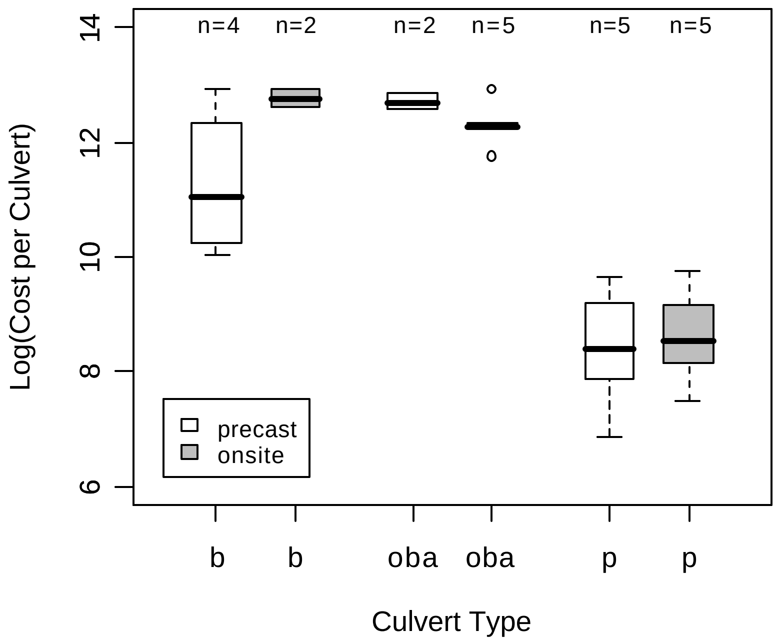

Figure 38. Boxplot of log(cost per culvert) by culvert type and construction type for our sample of one culvert replacement site per project. b = bridge, oba = open bottom arch, p = pipe.

Excavation

We asked restoration contractors to provide the number of cubic yards of fill excavated for each culvert replacement. We received data on this variable for 37 of the 42 culvert replacement projects.

Log-transformed cost per culvert was significantly positively associated with log-transformed excavation (Regression, coef. = 0.67, P = 0.0035, R^2adj = 0.29; Figure 39). An analysis of covariance with log(cost per culvert) as the response variable and log(excavation) and culvert type (bridge, open-bottom arch, or pipe) as the predictors was highly significant (ANCOVA, P = 3.296e-08, R^2adj = 0.82). The effect of log-transformed excavation was still marginally significant when controlling for the type of culvert (ANCOVA, coef. = 0.25, P = 0.054). Culvert type significantly affected log(cost per culvert) when controlling for log(excavation) (ANCOVA, P = 3.559e-07).

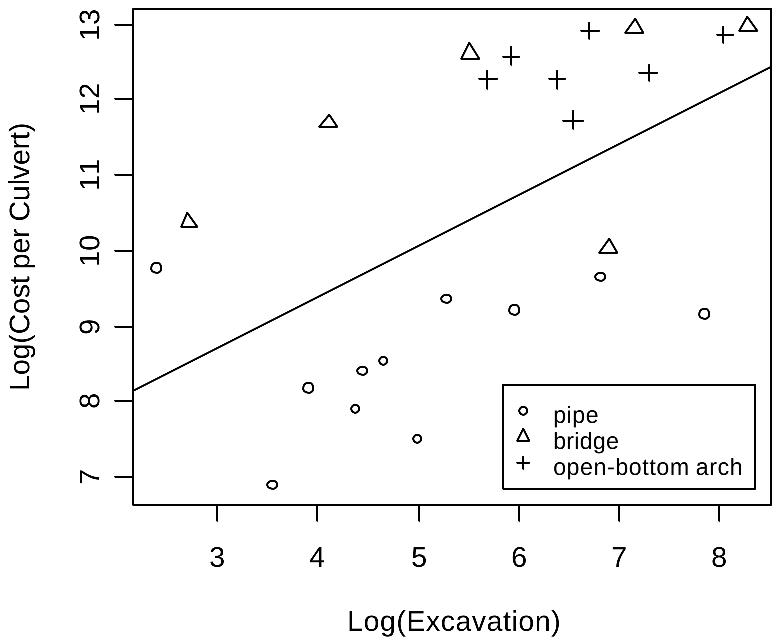

Figure 39. Log(cost per culvert) versus log(excavation). Line represents least squares fit. Excavation is measured in cubic yards.

Culvert Replacement Analysis Summary

The best predictor of cost for culvert replacement projects was the diameter of the replacement culvert. Diameter of the culvert explained 85% of the variability in cost per culvert. Culvert diameter was significantly positively dependent on stream flow, which was also positively associated with cost per culvert, explaining 63% of the variability in cost. As follows naturally from the relationship between cost per culvert and flow, there was also a significant relationship between cost per culvert and stream order: replacement of culverts on 2nd order streams cost significantly more than culvert replacements on 1^{st} order streams.

Other factors that affected the cost per culvert of culvert replacements included the type of road over the culvert (culverts below minor 2-lane roads cost more to replace than those below forest roads) and the amount of excavation that was done in replacing the culvert. Type of culvert also affected the cost of replacement; pipe culverts cost significantly less to replace than open-bottom arches and bridges.

Existing Culvert Improvement

We received data on only 3 sites that included cost information associated with existing culvert improvement. Each site was from a different project. Data for the three sites are reported in Table 50.

Table 50. Cost of culvert improvementby improvement type for the entire dataset.

Improvement Type	Cost	Cost per Foot	Weir Installed	Culvert Length (feet)
Other	$13,341	$111	Boulder weir	120
Washington baffles, metal	$17,944	$608	None	30
Other	$575		None	

For comparison, we also looked at the cost of culvert improvement for projects in the original CHRPD database from 3/14/05. Cost data in the CHRPD are recorded at the project level. To attempt to get accurate values of cost of existing culvert improvement, we limited the projects to those with only one task (existing culvert improvement), one measurement type, and one site per project. We also only looked at projects that began in 1998 or later. There was only one project that met these criteria in the CHRPD (Table 51).

Table 51. Culvert improvement cost data from the CHRPD (3/14/05). Sites are limited to projects since 1997 with only one task, one measurement type, and one site per project. Only one site met these criteria.

ProjID	DetailsID	Treatment	Total Cost	Measure	Units	Cost per Unit
720069	37	Culvert retrofitted with baffles or weirs	$9,395	2	baffle	$4,698

Instream Structures

We received data on 58 sites that included cost information associated with instream structures. The sites came from 38 different projects. There were between 1 and 10 sites per project (Table 52). Number of sites and cost statistics are reported in Tables 53 and 54. Sites in table 54 are a subset of the sites in Table53.

Table 52. Number of projects by number of sites per project for instream structures projects.

Number of Sites	Number of Projects
1	30
2	4
3	2
4	1
10	1

Table 53. Summary of instream structures cost per structure.

Number of Sites	Minimum Cost per Structure	Maximum Cost per Structure	Average Cost per Structure	Standard Deviation of Cost per Structure
58	$250	$175,000	$12,375	29,040

Table 54. Summary of instream structures cost per stream mile.

Number of Sites	Minimum Cost per Mile	Maximum Cost per Mile	Average Cost per Mile	Standard Deviation of Cost per Mile
45	$4,032	$46,757,000	$2,192,072	7,461,388

For comparison, we also looked at the cost of instream structures for projects in the original CHRPD database from 3/14/05 (Table55). Cost data in the CHRPD are recorded at the project level. To attempt to get accurate values of cost of instream structures, we limited the projects to those with only one task (instream structures), one measurement type, and one site per project. We also only looked at projects that began in 1998 or later. Only one of the selected instream structure projects from the CHRPD (704943) occurs in the new database, but no data was received for this project.

Table 55. Summary of instream structure cost data from the CHRPD (3/14/05). Sites are limited to projects since 1997 with only one task, one measurement type, and one site per project.

Number of Sites	Unit	Minimum Cost per Unit	Maximum Cost per Unit	Average Cost per Unit	Standard Deviation of Cost per Unit
11	structure	$214	$11,335	$2,563	3,133
5	mile	$220,528	$552,118	$364,521	163,890

Analysis

As was mentioned above, the new data that we collected from contractors included 58 sites with data for instream structures, from 38 different projects. Most statistical analyses require independence of samples, and clearly samples from the same project are not independent. So, for statistical analyses we randomly selected one site from each project and used this subset of the data for our analyses. Cost values are reported here as cost per structure. The number of sites with each number of structures is shown in Table56. Cost per structure ranged from $250.00 to $175,000.00 with an average of $12,374.85. The median cost per structure is $3,366.70.

Table 56. Number of sites by number of structures per site.

Number of Structures	Number of Sites
1	18
2	6
3	7
4	5
5	1
6	2
7	3
8	6
9	1
10	5

Number of Structures	Number of Sites
12	2
14	1
19	1

Material Type

We asked restoration contractors to provide the primary material type of the structures installed:

- wood = logs/rootwads/tree bundles
- rock/boulder = boulder/rock/cobble structures
- both = both wood and rock
- bioengineered = planting/placement of live plants/cuttings
- other = concrete/wire/geotextile fabric, etc.

We received information on the material type of the structures for all but one of the 58 instream structures sites. The number of sites and cost per site and per structure are provided in Tables 57 and 58. Additional categories were added for cement structures and for multiple material types when multiple types were provided by the contractor.

Table 57. Cost of instream structures by material type for the complete dataset.

Material Type	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
wood	15	$3,367	$16,766	$6,074	4,406	$3,367
rock/boulders	19	$500	$222,000	$38,500	60,455	$9,300
both	17	$8,000	$51,323	$19,748	12,390	$15,659
concrete/cement	3	$17,100	$93,514	$53,128	38,393	$48,769
multiple	2	$15,000	$94,000	$54,500	55,861	$54,500
other	1	$350,000	$350,000	$350,000		$350,000

Table 58. Cost per structure of instream structures by material type for the complete dataset.

Material Type	Number of Sites	Minimum Cost per Structure	Maximum Cost per Structure	Average Cost per Structure	Standard Deviation of Cost per Structure	Median Cost per Structure
wood	15	$882	$3,367	$2,721	1,031	$3,367
rock/boulders	19	$250	$39,302	$7,015	10,492	$2,878
both	17	$1,163	$51,323	$6,226	11,735	$3,500
concrete/cement	3	$4,275	$93,514	$48,853	44,620	$48,769
multiple	2	$1,250	$94,000	$47,625	65,584	$47,625
other	1	$175,000	$175,000	$175,000		$175,000

For our analyses, we focused on the three most common types of structures: those made from wood, rock, or both wood and rock. The other 3 categories had significantly higher costs per structure and had small sample sizes. We selected this subset of projects before sampling one site from each project. The resulting sample includes 32 sites. There are only 4 sites with wood structures in the sample because 10 of the 15 wood instream structure sites were from the same project and another project had 3 wood structure sites.

Cost per structure for the sample of sites was heavily skewed (Figure 40). We used log-transformed cost per structure for our analyses. Log-transformed cost per structure did not differ significantly among the three material types (Kruskal-Wallis chi-squared = 1.07, df = 2, P = 0.58; Figure 41).

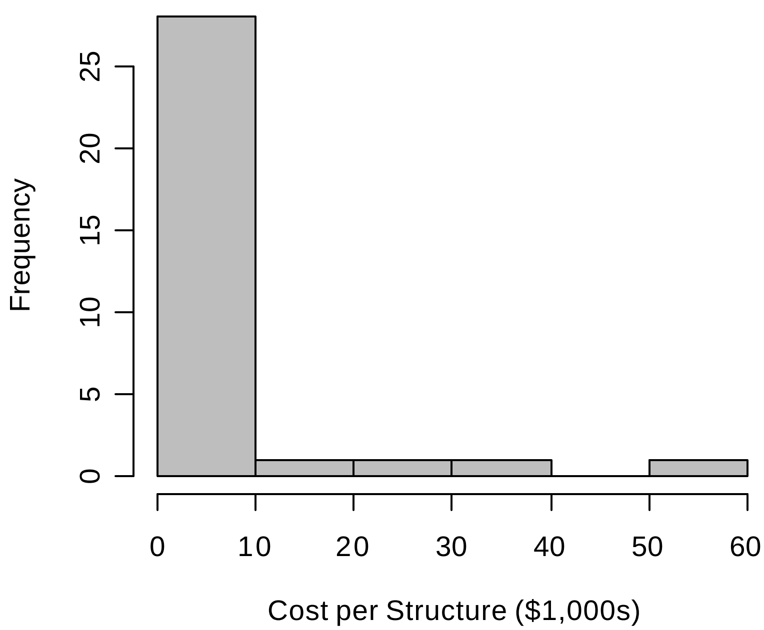

Figure 40. Histogram of cost per structure for our sample of one instream structure site per project.

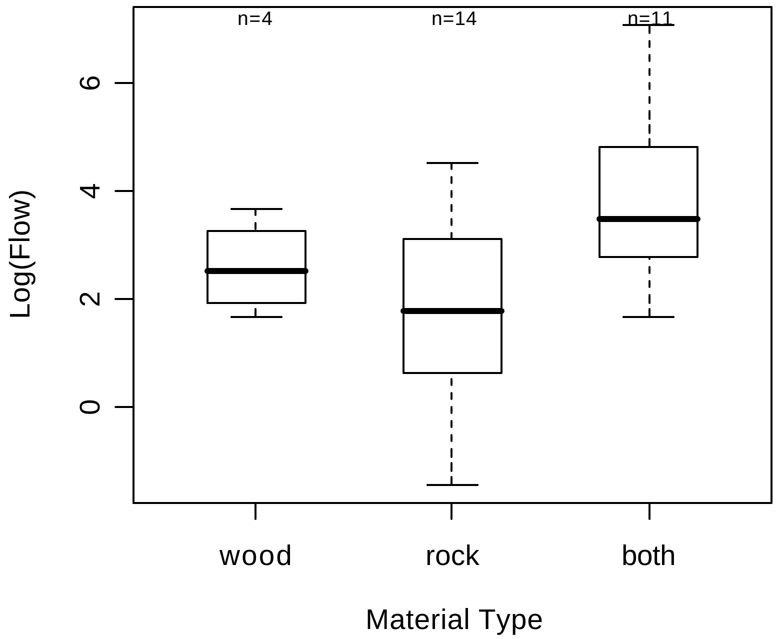

Figure 41. Boxplot of log(cost per structure) for each material type for our sample of one instream structure site per project.

Stream Characteristics

We asked restoration contractors to provide information on stream order as a surrogate for stream size: 1st order, 2nd order, or 3rd order and above. All 58 instream structure sites have associated stream orders. Stream order values provided by contractors were double-checked against routed hydrography data from the California Department of Fish and Game (CDFG). Of the 48 stream orders reported by contractors for instream structure sites with material types of wood, rock, or both, 17 (35%) were incorrect according to the CDFG stream data. These values were corrected (7 were higher than reported and 10 were lower). Sites were relatively evenly divided among the stream orders. There were 14 1st order sites, 18 2nd order sites, and 16 sites on streams 3rd order and above. Data for the number and cost of instream structure sites by stream order for our sample of one site per project are shown in Tables 59 and 60.

Table 59. Cost of instream structures by stream order for our sample of one instream structure site per project.

Stream Order	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
1st order	7	$500	$222,000	$54,232	84,807	$9,300
2nd order	13	$2,000	$138,577	$26,576	37,792	$12,096
3rd order and above	12	$1,723	$78,000	$23,475	21,432	$19,335

Table 60. Cost per structure of instream structures by stream order for our sample of one instream structure site per project.

Stream Order	Number of Sites	Minimum Cost per Structure	Maximum Cost per Structure	Average Cost per Structure	Standard Deviation of Cost per Structure	Median Cost per Structure
1st order	7	$250	$39,302	$11,124	15,716	$ 2000
2nd order	13	$882	$19,797	$4,767	5,042	$ 2878
3rd order and above	12	$862	$51,323	$6,848	14,118	$ 2538

Cost per structure did not differ significantly among stream orders (Kruskal-Wallis chi-squared = 0.13, df = 2, P = 0.94; Figure 42).

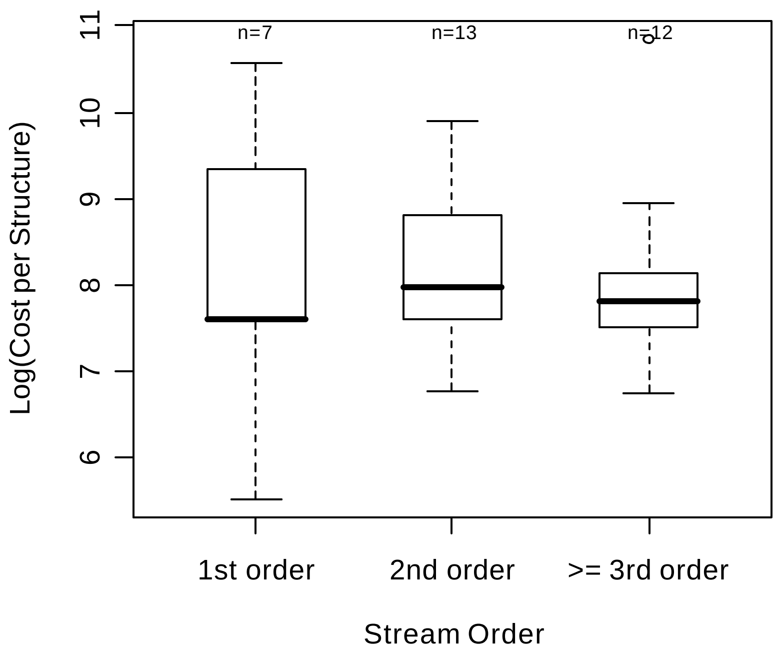

Figure 42. Boxplot of log(cost per structure) by stream order for our sample of one instream structure site per project.

Estimates of actual stream flow were derived using a program that estimates stream characteristics based on topography and rainfall (Miller, 2003). Sites were associated with streams output by this program in a GIS system based on proximity, and the flow for the reach that corresponded to the center of the site was recorded. Using this methodology, flow values could be estimated for 54 of the 58 instream structure sites. The remaining sites could not be unambiguously assigned to a stream in the DEM-derived hydrography.

Flow estimates were heavily right skewed (Figure 43). Log-transformed cost per structure was not significantly associated with log-transformed flow (Regression, P = 0.143, R^2adj = 0.043; Figure 44). We have low power to detect an effect of stream flow on cost because there is only one instream structure site on a high flow stream. As would be expected, stream flow differs significantly for the different stream orders (Kruskal-Wallis chi-squared =

17.45, df = 2, P = 0.00016; Figure 45). Material types also differed significantly with log-transformed stream flow (Kruskal-Wallis chi-squared = 7.65, df = 2, P = 0.02; Figure 46). Sites on higher flow streams tended to have structures made of both wood and rock.

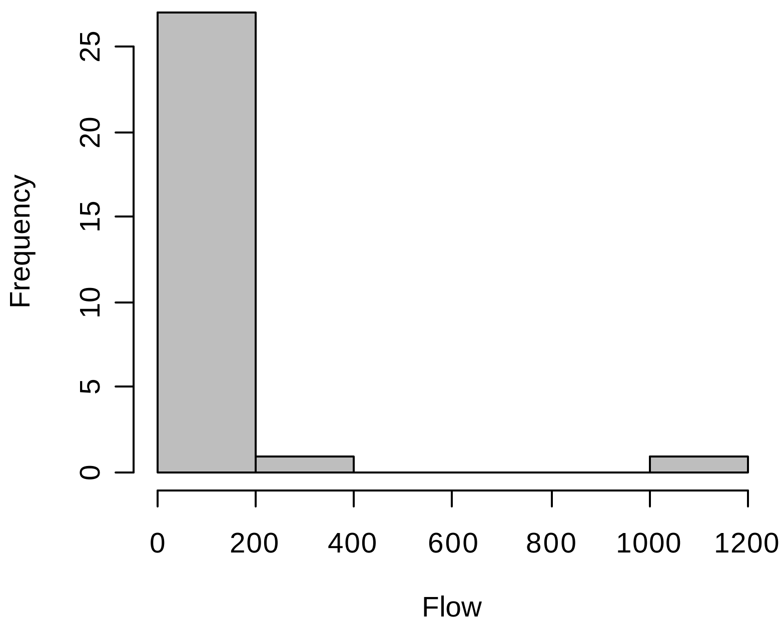

Figure 43. Histogram of stream flow for our sample of one instream structure site per project.

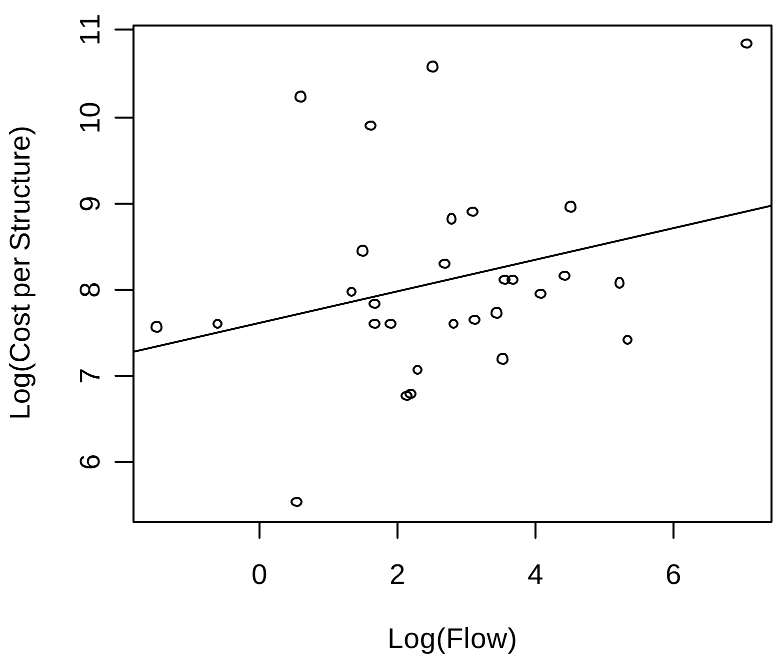

Figure 44. Log(cost per structure) versus log(stream flow) for our sample of one instream structure site per project. Line represents least squares fit. Flow values are measured in cubic feet per second.

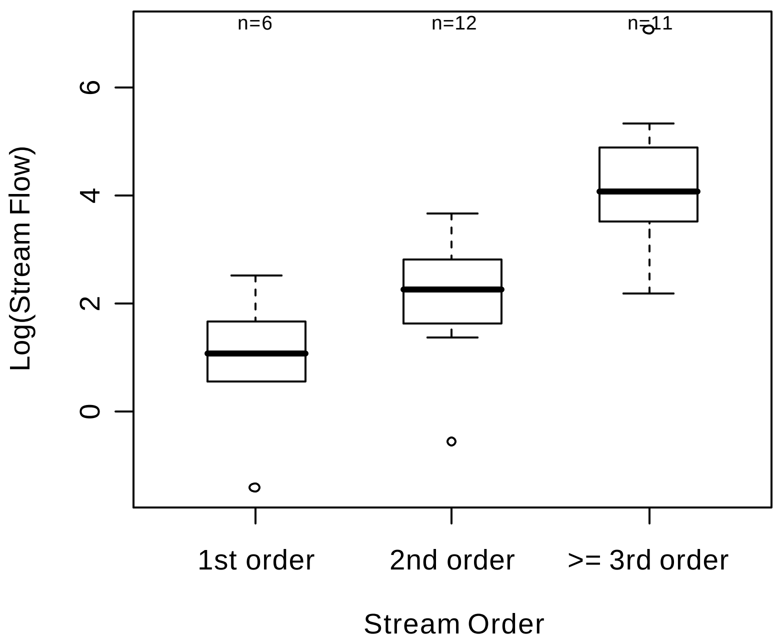

Figure 45. Boxplot of log(stream flow) for each stream order for our sample of one instream structure site per project. Flow values are measured in cubic feet per second.

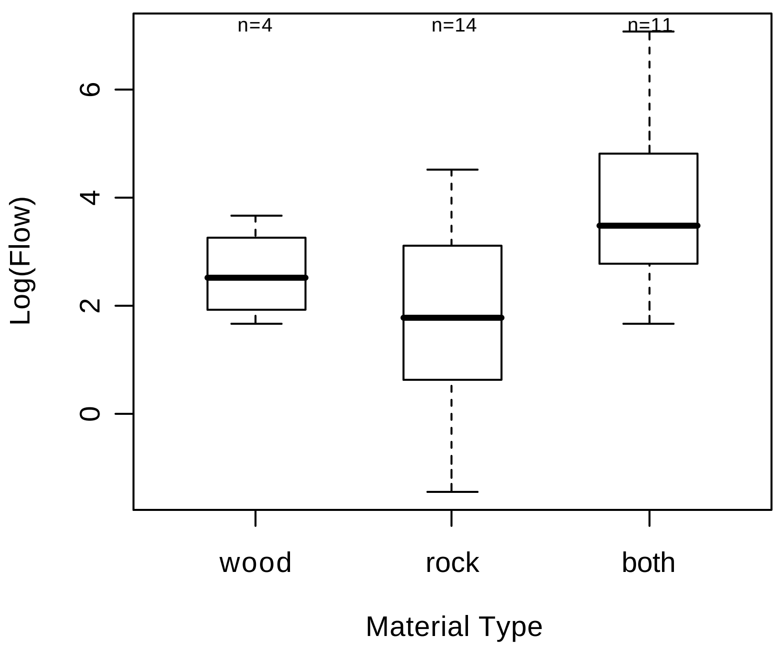

Figure 46. Boxplot of log(flow) by material type for instream structure sites for our sample of one instream structure site per project.

Project Size

There was not a significant relationship between number of structures per site and cost per structure (Regression, P = 0.44; Figure 47).

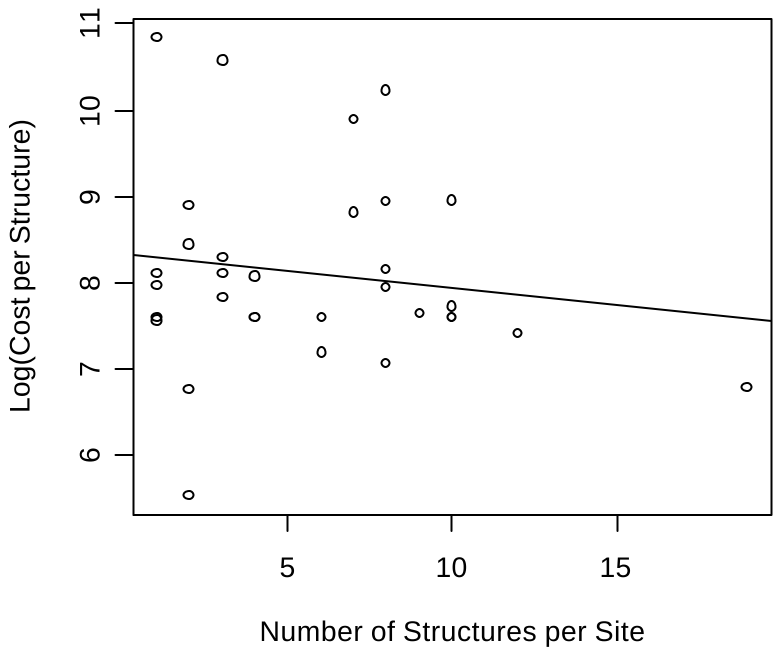

Figure 47. Log(cost per structure) versus number of structures per site for our sample of one instream structure site per project.

Material Size

We asked restoration contractors to provide the size of boulders (tons) and the diameter of wood (inches) used in the instream structures. We received data on rock size for 38 of the 58 instream structures projects; there was only one site that had a material type of rock size for which we did not receive information on the size of the rock. We received data on wood diameter for 34 of the 58 instream structures sites; we received data on wood diameter for all sites that had wood as a primary structure material. Some contractors provided a range of sizes for material type. In these cases, we used the average value for our analyses. There was a marginally significant effect of rock size on cost per structure (Regression, coef. = 0.25, P = 0.09, R^2adj = 0.075; Figure 48). There was not a significant relationship between log-transformed cost per structure and wood diameter (Regression, P = 0.27; Figure 49).

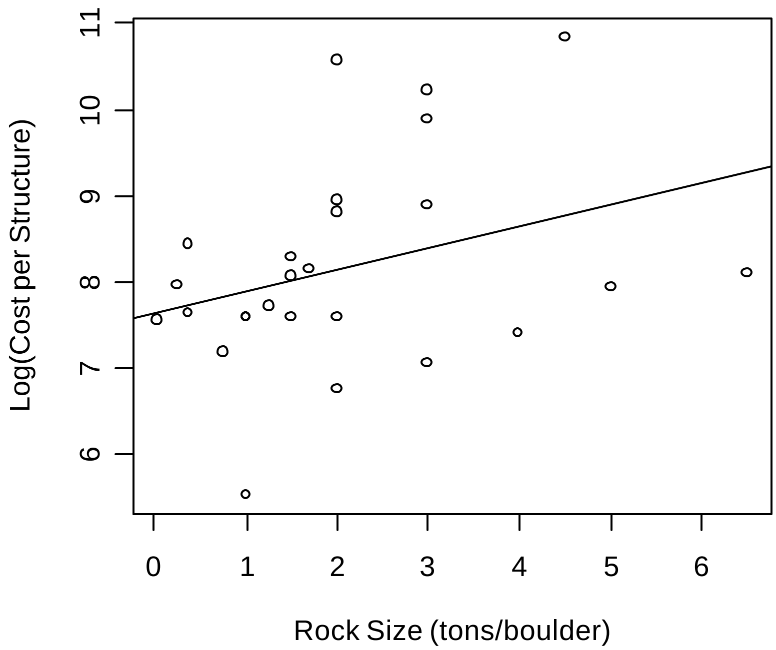

Figure 48. Log(cost per structure) versus rock size (tons/boulder) for our sample of one instream structure site per project.

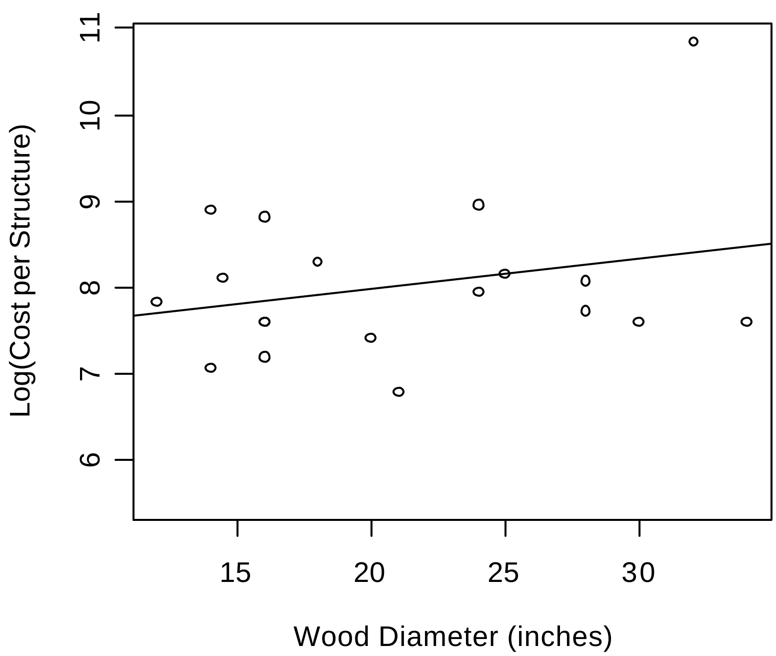

Figure 49. Log(cost per structure) versus wood diameter (inches) for our sample of one instream structure site per project.

Distance to Materials

We asked restoration contractors to provide information on the distance to materials. We received data on distance to materials for 42 of the 58 sites. Some contractors gave multiple distances when multiple types of materials were used. In these cases we used the maximum distance.

Log-transformed cost per structure was not significantly associated with the distance to materials for the sample of one site per project (Regression, P = 0.151; Figure 50). For the subset of these sites that have rock as the primary material type, however, there was a significant association between log-tranformed cost per structure and distance to materials (Regression, coef = 0.070, P = 0.0052, R^2adj = 0.48; Figure 51).

We also asked restoration contractors whether materials were available onsite. This question was asked as a checkbox, so unchecked boxes indicate that the materials were not available onsite, but could also indicate no response to the question. There was not a significant difference in log-transformed cost per structure for sites with materials available onsite compared with sites where materials were not available onsite (Wilcoxon signed rank test, W = 103, P = 0.24; Figure 52).

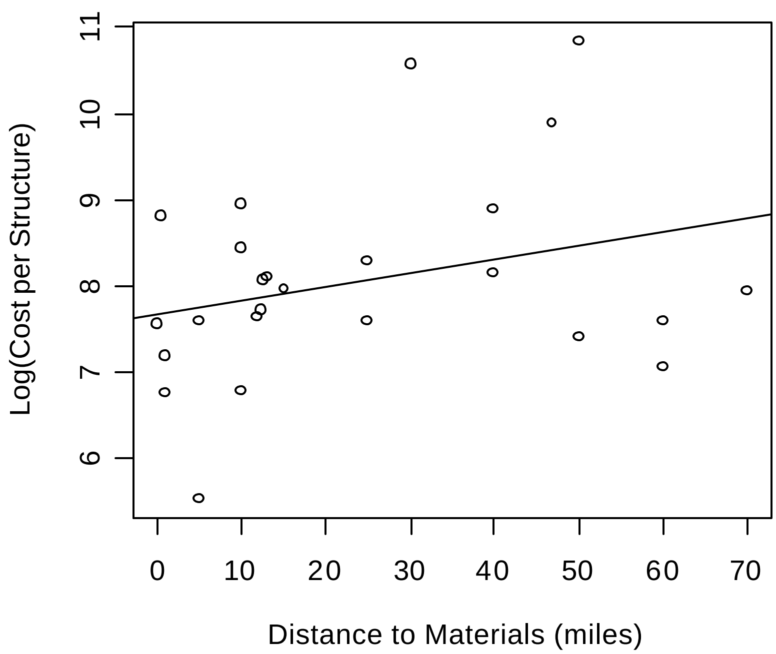

Figure 50. Log(cost per structure versus distance to materials (miles) for our sample of one instream structure site per project.

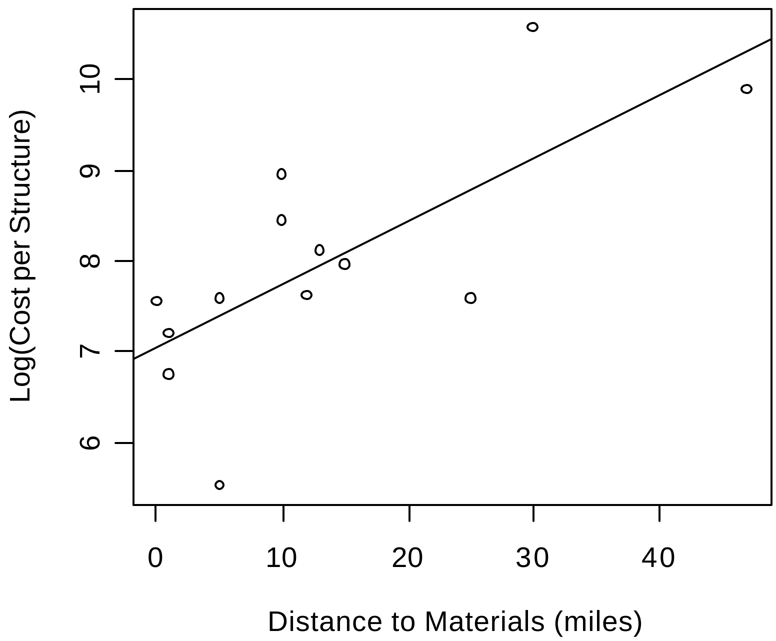

Figure 51. Log(cost per structure) versus distance to materials (miles) for the subset of sites with rock as the primary structure material.

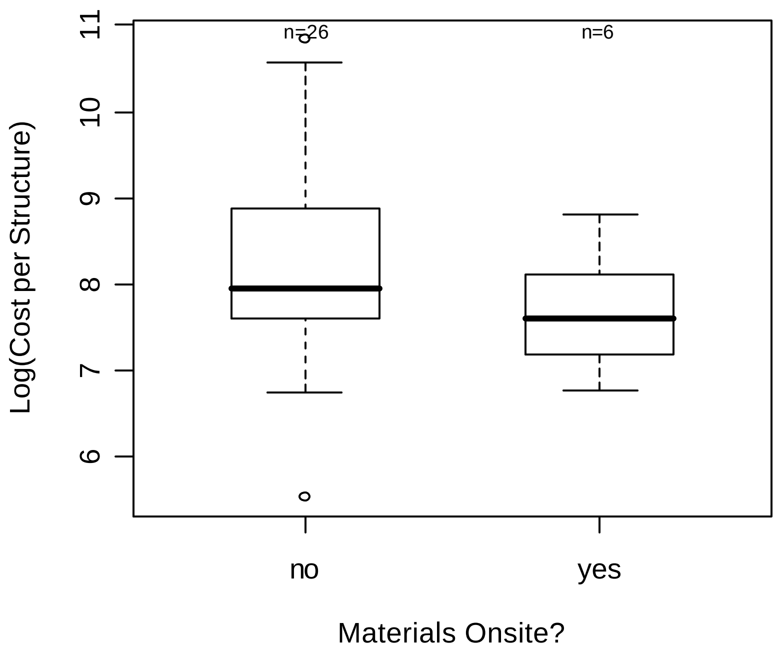

Figure 52. Boxplot of log(cost per structure) for instream structures sites with and without materials available onsite for our sample of one instream structure site per project.

Site Accessibility

There was not a significant association between site accessibility and log-transformed cost per structure (Kruskal-Wallis chi-squared = 2.99, df = 2, P = 0.22; Figure 53).

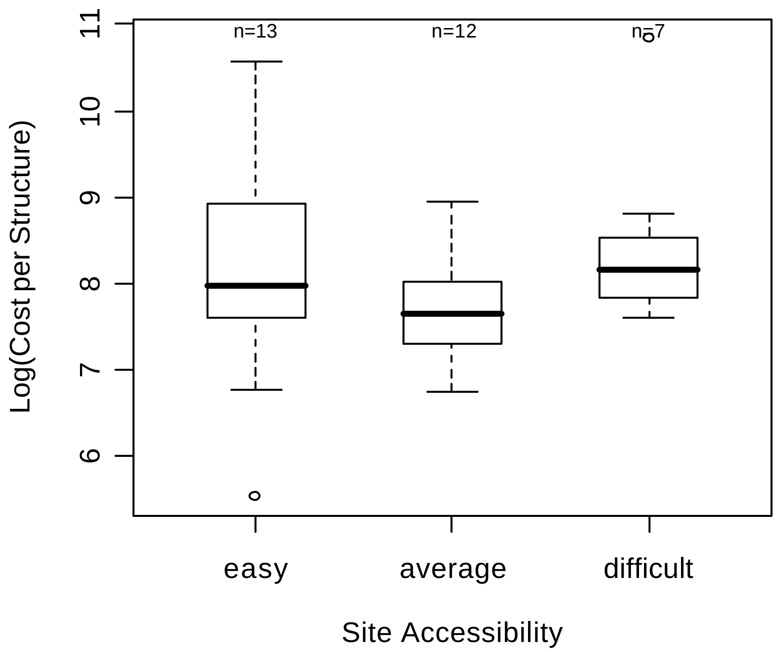

Figure 53. Boxplot of log(cost per acre) for each site accessibility class for our sample of one instream structure site per project.

Design Costs/Risk

A factor that can possibly affect the cost of instream structures placement is the design cost of the project, which increases with the level of risk involved. The risks involved with instream structures placement include possible flooding and hazards to people using the stream. Proper design can minimize the risks but will increase the cost of the project. For this reason, we would expect the cost of instream structure placement to be higher on more heavily used streams and streams near urban areas. We did not ask contractors to provide information on these variables. Possible surrogates for risk include population density and distance from the site to the nearest urban area.

Population density estimates for places and balance of county areas were derived from the US Census Bureau 2000 Census data. The units of population density are people per square mile. These data were associated with restoration sites using GIS. Log transformed cost per structure was marginally significantly positively associated with Box-Cox transformed population density (power = -0.4) (Regression, P = 0.10; Figure 54).

Distance from each site to the nearest urban area was estimated using Geographical Information Systems (GIS) software. We used the urban areas from the US Census Bureau TIGER/Line data, which are defined as densely settled territories that contain 50,000 or more people. The distance from the edge of each site feature to the edge of the nearest urban area was calculated using the Spatial Join tool in ArcMap 9.1 for lines and points and using the Nearest Features script for ArcView 3.2 by Jeff Jenness for polygons. There was not a significant association between log-transformed cost per structure and distance to the nearest urban area (Regression, P = 0.561; Figure 55).

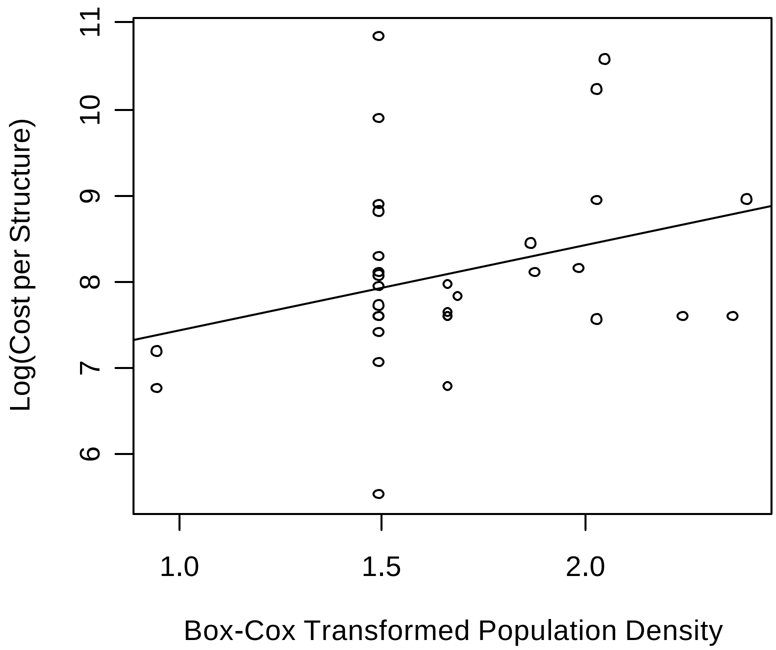

Figure 54. Log(cost per structure) versus box-cox transformed population density (power = -0.4) for our sample of one instream structure site per project.

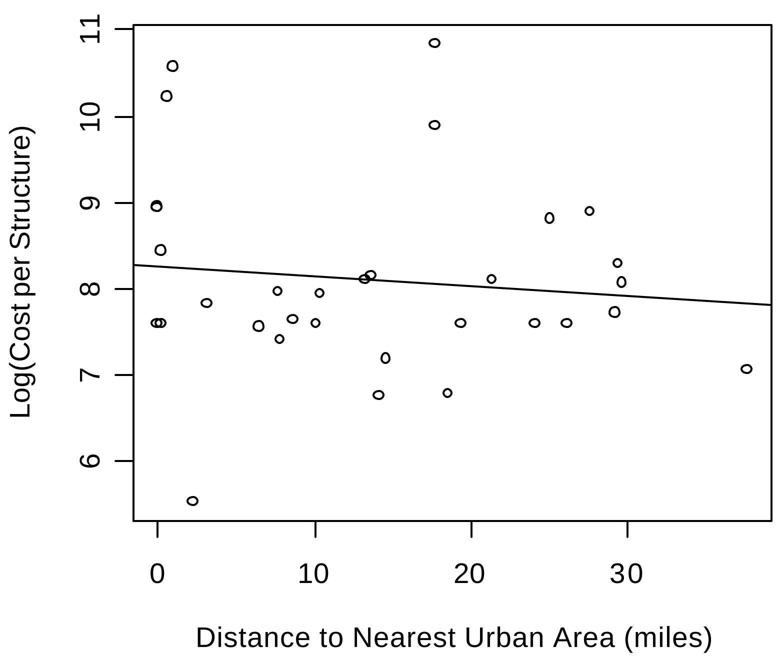

Figure 55. Log(cost per structure) versus distance to nearest urban area (miles) for our sample of one instream structure site per project.

Labor Cost

As a surrogate for labor costs, we collected information on unemployment rates and construction salaries from the California Employment Development Department (CalEDD) and Rand California respectively. Unemployment rates are county level Labor Force Data from the Labor Market Information Division of the CalEDD. Average annual construction wages are for 'Heavy and Civil Engineering Construction' from the Covered Employment and Wages (CEW) program of the Bureau of Labor Statistics but were acquired from Rand California. Data from both datasets are at the county level and were assigned to sites based on the county the site occurs within and the year the project began. When sites overlapped multiple counties, the data were assigned to sites based on a weighted average of how much of each site occurs within each county. Some sites are missing construction wage data because data are not available for all counties for each year.

There was a significant negative association between log-transformed cost per structure and average unemployment rate (Regression, coef = -35.01, P = 0.011, R^2adj = 0.17; Figure 56). There was not a significant relationship between log-transformed cost per structure and average annual construction wages (Regression, P = 0.25, Figure 57).

We also asked contractors whether they were required to pay prevailing wages. There was not a significant association between log-transformed cost and whether or not prevailing wages were required (Wilcoxon rank sum test, P = 0.22).

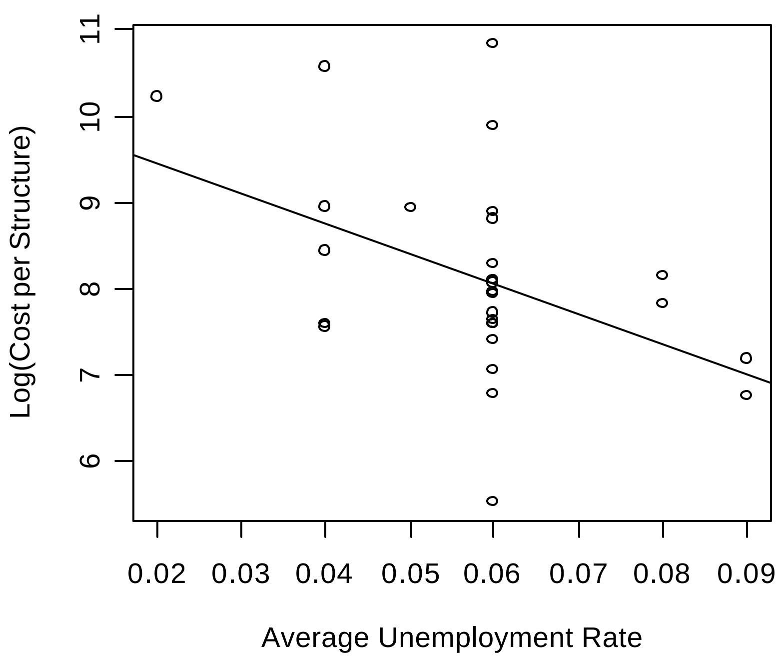

Figure 56. Log(cost per structure) versus average annual unemployment rate for our sample of one instream structure site per project.

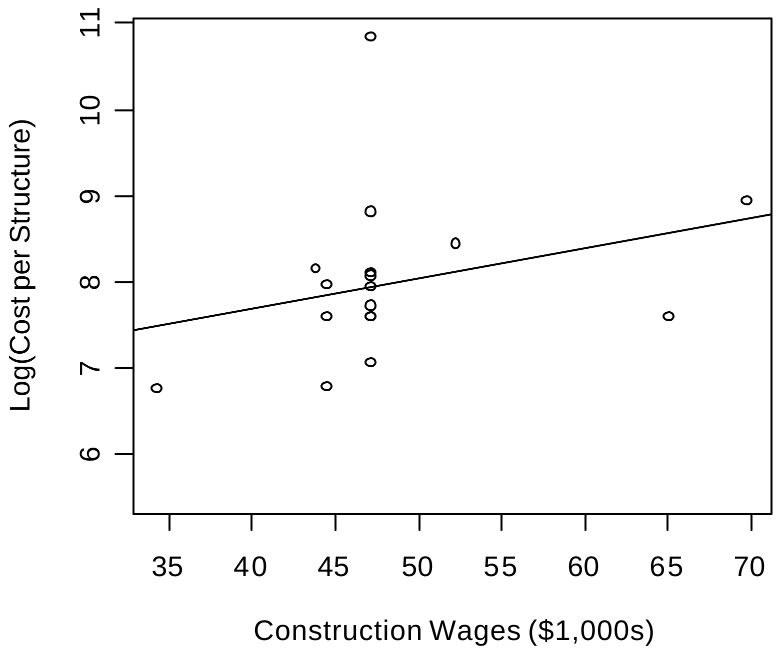

Figure 57. Log(cost per structure) versus average annual construction wages for our sample of one instream structure site per project.

Instream Structures Analysis Summary

Most of the factors that we looked at did not significantly affect the cost of instream structure restoration projects. The only variable that had a significant effect on cost per structure was average unemployment rate, which only explained 17% of the variability in cost. There were marginally significant positive effects of rock size and population density (Box-Cox transformed) on log-transformed cost per structure. In addition, isolating just the instream structures with rock as the primary structure material, there was a significant positive effect of distance to materials on log-transformed cost per structure.

There are many sources of error in our data and analyses. A fundamental problem with our analyses is that we are looking at each variable individually because our sample sizes are too small for the type of multivariate analyses we would like to conduct. In addition, to this overarching issue, there are potential problems with the data themselves. An example of this is the material type data for the instream structures projects. We asked contractors to provide the primary structure material. Some contractors gave one material type, and others identified multiple types. It is possible that some of the sites that have only one material type listed actually had multiple materials, so there is the potential for inconsistencies in this variable.

Bank Stabilization

We received data on 53 sites that included cost information associated with bank stabilization. The sites came from 38 different projects. There were between 1 and 5 sites per project (Table 1). Number of sites and cost statistics are reported in Table62.

Table 61. Number of projects by number of sites per project for bank stabilization projects.

Number of Sites	Number of Projects
1	29
2	6
3	1
4	1
5	1

Table 62. Summary of bank stabilization cost per foot.

Number of Sites	Minimum Cost per Foot	Maximum Cost per Foot	Average Cost per Foot	Standard Deviation of Cost per Foot
53	$4	$895	$124	198

For comparison, we also looked at the cost of bank stabilization for projects in the original CHRPD database from 3/14/05 (Table63). Cost data in the CHRPD are recorded at the project level. To attempt to get accurate values of cost of bank stabilization, we limited the projects to those with only one task (bank stabilization), one measurement type, and one site per project. We also only looked at projects that began in 1998 or later. There were only 4 projects meeting these criteria. None of the selected bank stabilization projects from the CHRPD occur in the new database.

Table 63. Summary of bank stabilization cost data from the CHRPD (3/14/05). Sites are limited to projects since 1997 with only one task, one measurement type, and one site per project.

Number of Sites	Unit	Minimum Cost per Unit	Maximum Cost per Unit	Average Cost per Unit	Standard Deviation of Cost per Unit
3	foot	$31	$97	$54	37
1	acre	$335	$335	$335	

Analysis

As was mentioned above, the new data that we collected from contractors included 53 sites with data for bank stabilization, from 38 different projects. Most statistical analyses require independence of samples, and clearly samples from the same project are not independent. So, for statistical analyses we randomly selected one site from each project and used this subset of the data for our analyses. Cost values are reported here as cost per foot of bank treated. Cost per foot ranged from $4 to $895 with an average of $124. The median cost per foot is $50.

Project Size

There was not a significant effect of project size on log-transformed cost per foot of bank stabilization (Regression, P = 0.51; Figure 58).

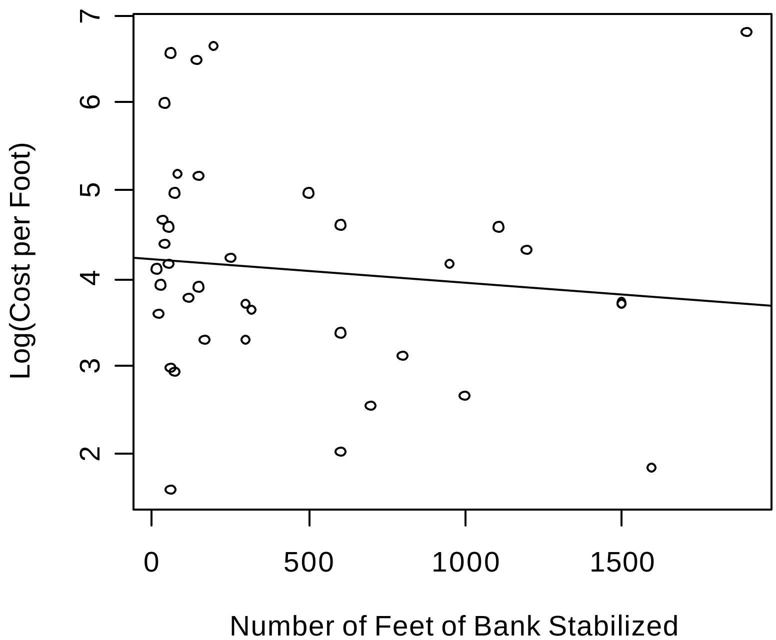

Figure 58. Log(cost per foot) versus number of feet of bank stabilized for our sample of one stream bank stabilization site per project.

Stream Characteristics

We asked restoration contractors to provide information on stream order as a surrogate for stream size: 1st order, 2nd order, or 3rd order and above. Of the 53 bank stabilization projects, 52 have associated stream orders, and one is an upslope project. Stream order values provided by contractors were double-checked against routed hydrography data from the California Department of Fish and Game (CDFG). Of the 52 stream orders reported by contractors for stream bank stabilization sites, 12 (23%) were incorrect according to the CDFG stream data. These values were corrected (7 were higher than reported and 5 were lower). There were 15 1st order sites, 12 2nd order sites, and 25 sites on streams 3rd order and above. Data for the number and cost of bank stabilization sites by stream order in our sample of one site per project are shown in Tables 64 and 65.

Table 64. Cost of bank stabilization by stream order for the sample of one site for each project.

Stream Order	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
1st order	7	$1,500	$26,400	$10,997	8,530	$1,000
2nd order	10	$290	$62,000	$15,023	17,611	$13,095
3rd order and above	20	$1,180	$1,700,000	$124,697	373,319	$30,152

Table 65. Cost per foot of bank stabilization by stream order for the sample of one site for each project.

Stream Order	Number of Sites	Minimum Cost per Foot	Maximum Cost per Foot	Average Cost per Foot	Standard Deviation of Cost per Foot	Median Cost per Foot
1st order	7	$40	$176	$88	53	$40
2nd order	10	$5	$394	$77	122	$5
3rd order and above	20	$6	$895	$196	289	$6

Cost per foot did not differ significantly among stream orders (Kruskal-Wallis chi-squared = 3.51, df = 2, P = 0.17; Figure 59).

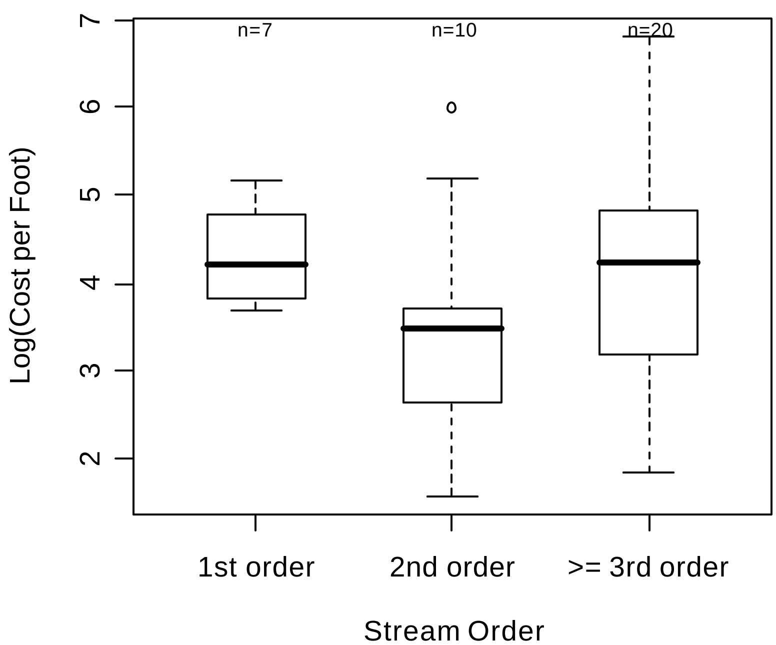

Figure 59. Boxplot of log(cost per foot) of bank stabilization by stream order for the sample of one site per project.

Estimates of actual stream flow were derived using a program that estimates stream characteristics based on topography and rainfall (Miller, 2003). Sites were associated with streams output by this program in a GIS system based on proximity, and the flow for the reach that corresponded to the center of the site was recorded. Using this methodology, flow values could be estimated for 44 of the 52 instream sites. The remaining sites could not be unambiguously assigned to a stream in the DEM-derived hydrography.

Flow estimates were heavily right skewed (Figure 60). Log-transformed cost per foot was marginally significantly associated with log-transformed flow (Regression, coef. = 0.16, P = 0.10, R^2adj = 0.059; Figure 61).

As would be expected, stream flow differs significantly for the different stream orders (Kruskal-Wallis chi-squared = 16.59, df = 2, P = 0.00025; Figure 62).

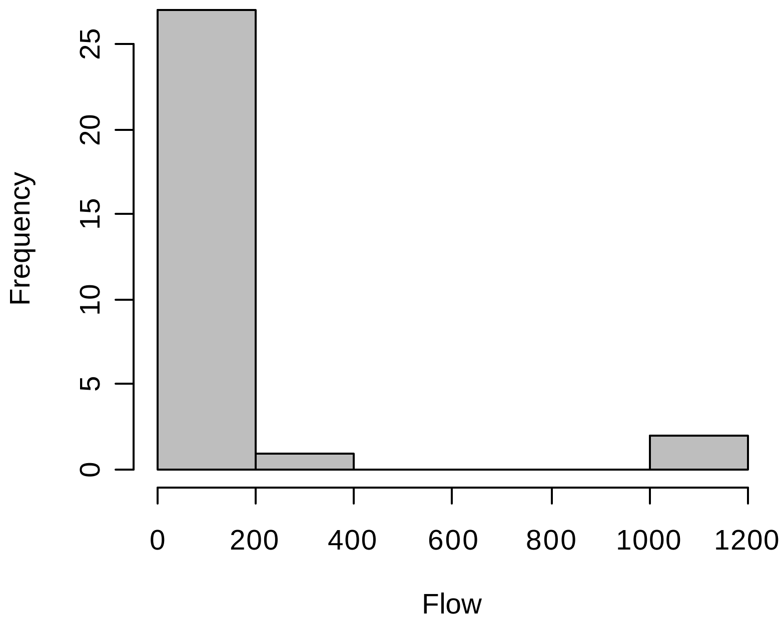

Figure 60. Histogram of stream flow for the sample of bank stabilization sites.

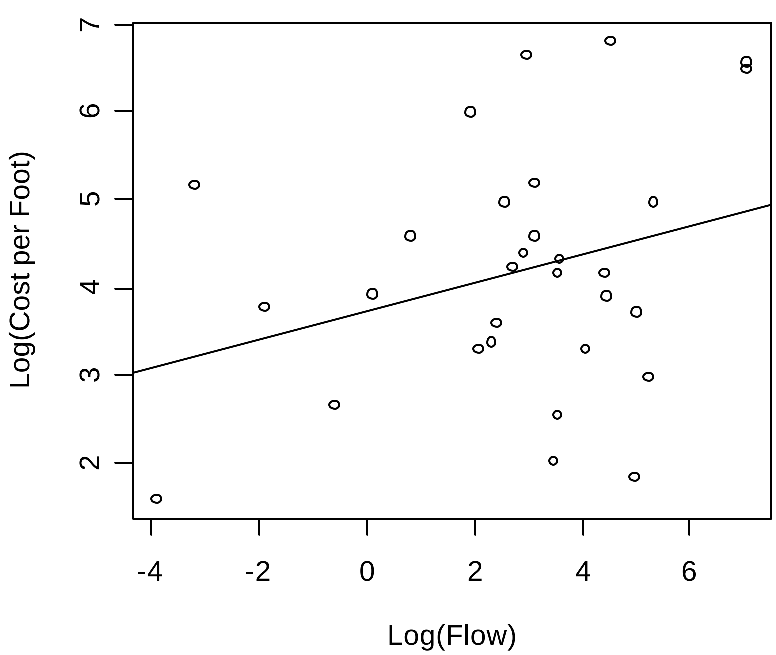

Figure 61. Log(cost per structure) versus log(stream flow) for the sample of one bank stabilization site per project. Line represents least squares fit. Flow values are measured in cubic feet per second.

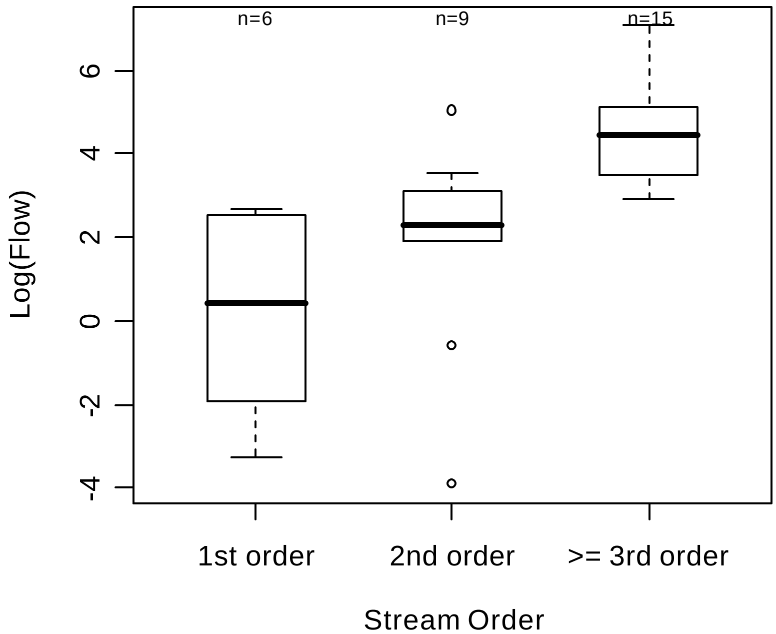

Figure 62. Boxplot of log(stream flow) for each stream order. Flow values are measured in cubic feet per second.

Excavation

We asked restoration contractors to provide information about the amount of excavation:

- minimal = hand tools
- moderate = small equipment, moderate excavation
- extensive = heavy equipment, slope reconstruction

Excavation data were provided for all 53 bank stabilization sites. Cost data by excavation amount are shown in Tables 66 and 67. There was not a significant difference in log-transformed cost per foot among the different excavation classes (Kruskal-Wallis chi-squared = 1.89, df = 2, p-value = 0.39; Figure 63).

Table 66. Cost of bank stabilization by excavation amount for the complete dataset.

Excavation	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
minimal	13	$290	$72,000	$12,438	19,328	$ 5,000
moderate	14	$800	$150,000	$28,650	39,598	$ 14,215
extensive	26	$895	$1,700,000	$91,007	329,759	$ 9,900

Table 67. Cost per foot of bank stabilization by excavation amount for the complete dataset.

Excavation	Number of Sites	Minimum Cost per Foot	Maximum Cost per Foot	Average Cost per Foot	Standard Deviation of Cost per Foot	Median Cost per Foot
minimal	13	$5	$176	$64	52	$46
moderate	14	$6	$750	$98	192	$41
extensive	26	$4	$895	$168	239	$83

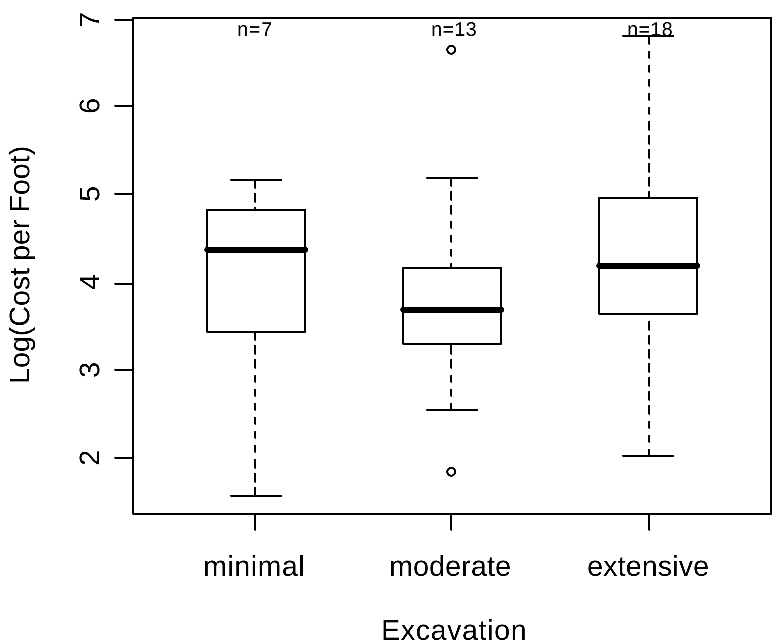

Figure 63. Boxplot of log(cost per foot) for each excavation type for the samples of one bank stabilization site per project.

Material Complexity

We asked contractors to provide the complexity of the materials used for the bank stabilization:

- minimal = native channel gravel/rock, available onsite
- moderate = riprap, onsite plants
- substantial = large logs (>24" diameter), large rootwads, large toe rock, offsite plants

Material complexity data were provided for all 53 bank stabilization sites. Cost data by material complexity category for the complete database are summarized in Tables 68 and 69. There was a trend for log-transformed cost to increase with material complexity, but the differences in cost among the material complexity classes were not statistically significant (Kruskal-Wallis chi-squared = 4.47, df = 2, P = 0.11; Figure 64).

Table 68. Cost of bank stabilization by material complexity for the complete dataset.

Material Complexity	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
minimal	10	$290	$12,000	$5,142	4,433	$4,082
moderate	25	$800	$150,000	$33,526	39,621	$15,750
substantial	18	$3,010	$1,700,000	$113,300	396,673	$9,900

Table 69. Cost per foot of bank stabilization by material complexity for the complete dataset.

Material Complexity	Number of Sites	Minimum Cost per Foot	Maximum Cost per Foot	Average Cost per Foot	Standard Deviation of Cost per Foot	Median Cost per Foot
minimal	10	$5	$59	$30	17	$ 31
moderate	25	$4	$750	$120	191	$ 48
substantial	18	$6	$895	$181	245	$ 98

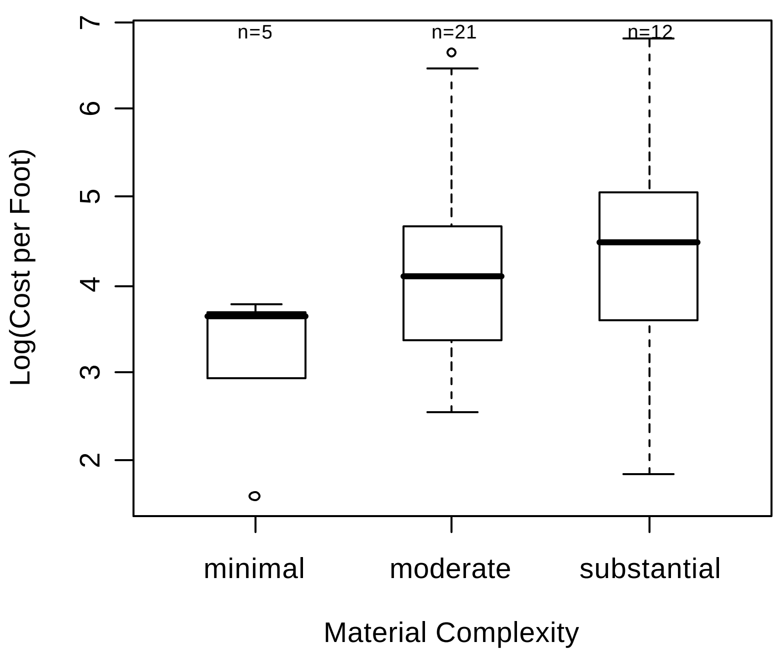

Figure 64. Boxplot of log(cost per foot) for each material complexity class for the sample of one bank stabilization site per project.

There was also a marginally significant difference in stream flow among the material complexity classes (Kruskal-Wallis chi-squared = 5.058, df = 2, p-value = 0.080; Figure 65).

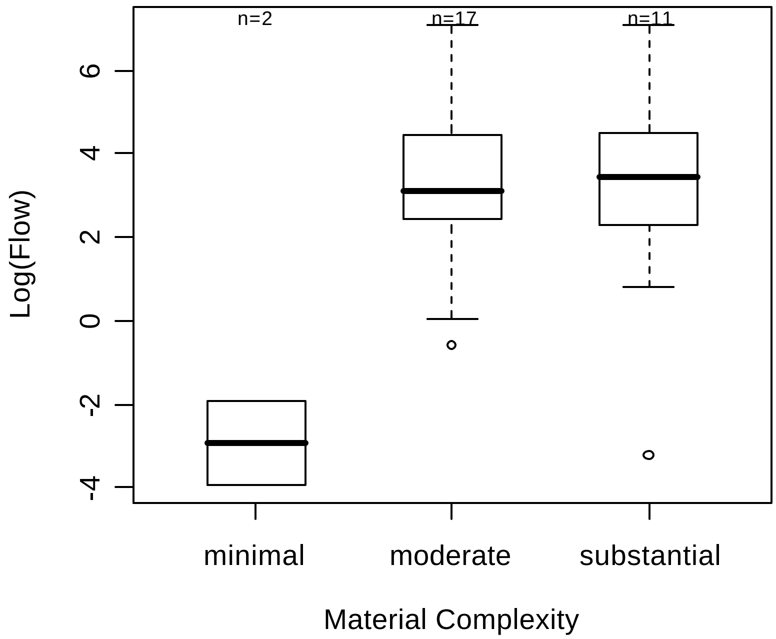

Figure 65. Boxplot of log(flow) for each material complexity class for the sample of one bank stabilization site per project. Flow is measured in cubic feet per second.

Material Type

We also asked restoration contractors to provide the type of material used for bank stabilization. The same category choices were given for bank stabilization as were given for instream structures:

- wood = logs/rootwads/tree bundles
- rock/boulder = boulder/rock/cobble structures
- both = both wood and rock
- bioengineered = planting/placement of live plants/cuttings
- other = concrete/wire/geotextile fabric, etc.

We received information on material type for 52 of the 53 bank stabilization sites. Cost data by material type are shown in Tables 70 and 71. There was not a significant difference in log-transformed cost per foot among sites with different material types (Kruskal-Wallis chi-squared = 6.55, df = 4, P = 0.16; Figure 66). Log-transformed cost per foot of bioengineered materials was invariant with regard to material complexity, but tended to be lower for rock materials of minimal complexity than for rock materials of moderate/substantial complexity (Figure 67).

Table 70. Cost of bank stabilization by material type for the complete dataset.

Material Type	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
bioengineered	14	$1,180	$108,750	$18,718	29,728	$1,180
rock	26	$290	$1,700,000	$84,970	331,063	$290
rock and	4	$21,230	$72,000	$49,384	22,460	$21,230

Material Type	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
wood						
multiple	6	$4,450	$90,000	$30,334	36,245	$4,450
other	2	$1,300	$9,000	$5,150	5,445	$1,300

Table 71. Cost per foot of bank stabilization by material type for the complete dataset.

Material Type	Number of Sites	Minimum Cost per Foot	Maximum Cost per Foot	Average Cost per Foot	Standard Deviation of Cost per Foot	Median Cost per Foot
bioengineered	14	$6	$143	$60	40	$44
Rock	26	$5	$895	$159	238	$64
rock and wood	4	$41	$705	$329	299	$284
Multiple	6	$8	$75	$33	23	$26
Other	2	$4	$19	$11	11	$11

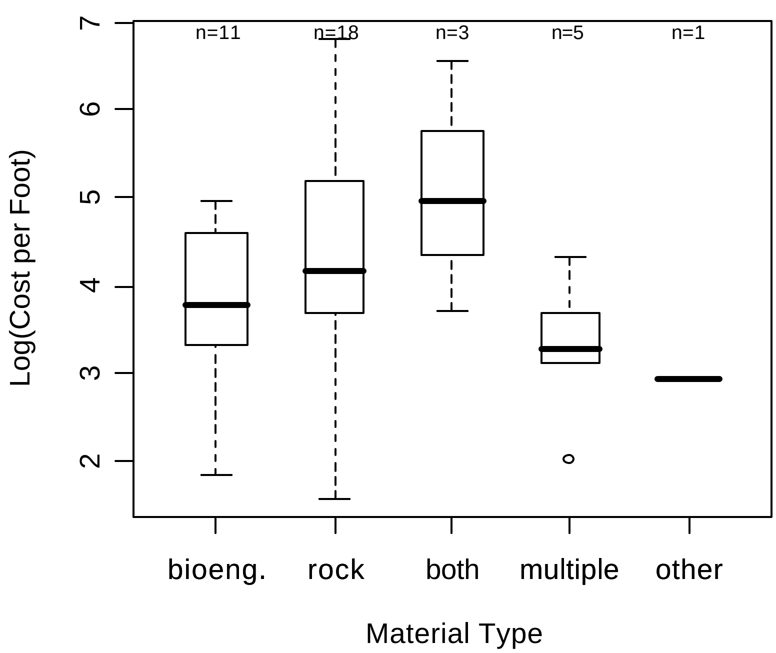

Figure 66. Boxplot of log(cost per foot) for each material type for the sample of one bank stabilization site per project. Material types: bioengineered, rock, both rock and wood, multiple types, and other.

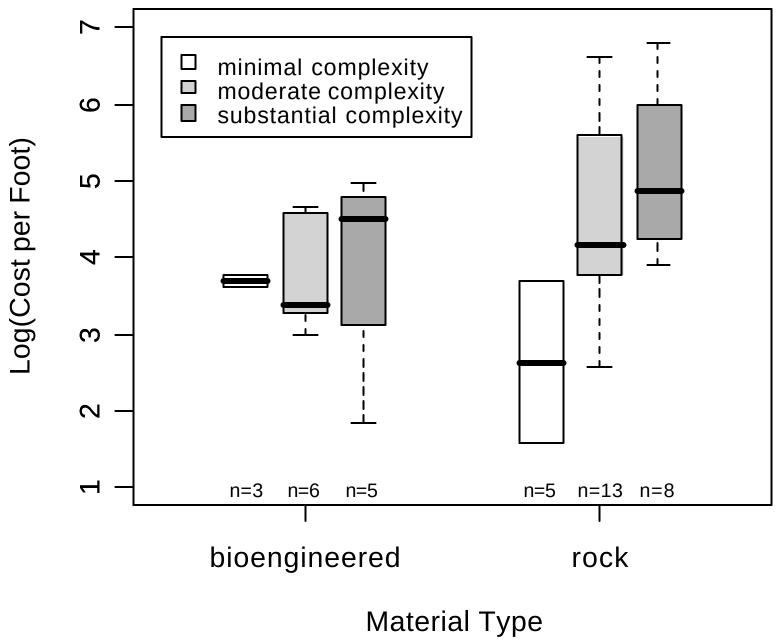

Figure 67. Boxplot of log(cost per foot) for each material type by each material complexity level for the sample of one bank stabilization site per project.

Labor Cost

As a surrogate for labor costs, we collected information on unemployment rates from the California Employment Development Department (CalEDD). Unemployment rates are county level Labor Force Data from the Labor Market Information Division of the CalEDD. Data are at the county level and were assigned to sites based on the county associated with the site and the year the project began. When sites overlapped multiple counties, the data were assigned to sites based on a weighted average of how much of each site occurs within each county.

There was not a significant association between log-transformed cost per foot and average unemployment rate (Regression, $P = 0.78$).

We also asked contractors whether they were required to pay prevailing wages. There was a marginally significant difference in log-transformed cost between sites where prevailing wages were and were not required (Wilcoxon rank sum test, $P = 0.055$; Figure 68).

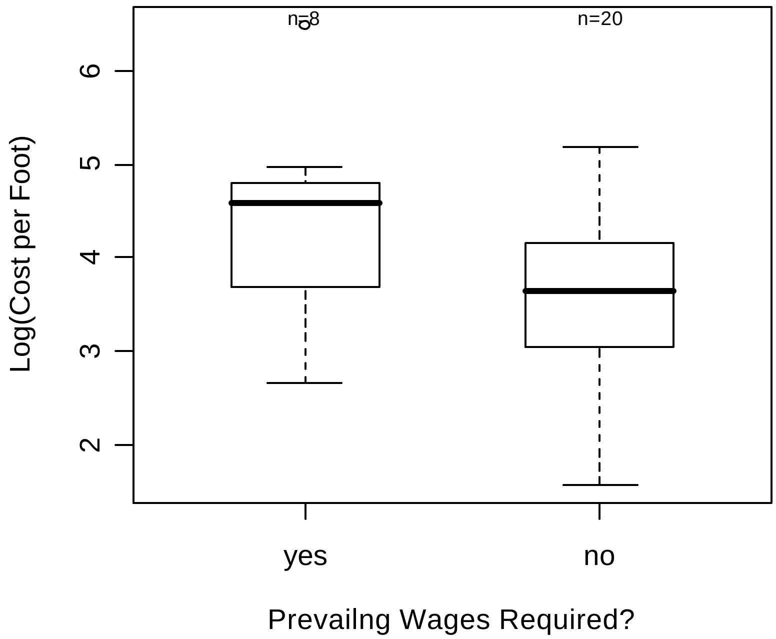

Figure 68. Boxplot of log(cost per foot) for sites where prevailing wages were and were not required for our sample of one bank stabilization site per project.

Stream Flow and Prevailing Wages

Controlling for whether prevailing wages were required, there was a significant positive effect of log-transformed flow on log-transformed cost per foot of bank stabilization (Table72).

Table 72. Regression coefficients, response = log(cost per foot), overall R^2adj = 0.41, P = 0.0032.

	Estimate	Standard Error	t value	Pr(>|t|)
(Intercept)	4.049	0.38	10.74	2.94e-09
log(Flow)	0.25	0.078	3.18	0.0052
Prevailing Wage Required: No	-1.24	0.42	-2.96	0.0085

Bank Stabilization Analysis Summary

None of the factors that we looked at significantly affected the cost (per foot) of bank stabilization projects when examined individually. Three variables had marginally significant effects on bank stabilization cost: stream flow, material complexity, and prevailing wages requirements. Sites in streams with higher flow tended to have higher costs per foot, and sites with minimal material complexity tended to have lower cost per foot of bank stabilization, but there were only two sites in this category. Sites where prevailing wages were required tended to cost more than sites where prevailing wages were not required. Controlling for whether prevailing wages were required, stream flow was significantly positively associated with cost per foot of bank stabilization.

Road Decommissioning

We received data on 52 sites that included cost information associated with road decommissioning. 51 of those included one or more size metrics. The sites came from 21 different projects. There were between 1 and 5 sites per project (Table73). Number of sites and cost statistics are reported in Tables–74 - 76.

Table 73. Number of projects by number of sites per project for road decommissioning projects.

Number of Sites	Number of Projects
1	7
2	4
3	6
4	1
5	3

Table 74. Summary of road decommissioning cost.

Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
52	$300	$85,806	$13,751	21,002	$4,679

Table 75. Summary of road decommissioning cost per crossing.

Number of Sites	Minimum Cost per Crossing	Maximum Cost per Crossing	Average Cost per Crossing	Standard Deviation of Cost per Crossing	Median Cost per Crossing
40	$262	$17,060	$3,884	4,335	$1,932

Table 76. Summary of road decommissioning cost per mile.

Number of Sites	Minimum Cost per Mile	Maximum Cost per Mile	Average Cost per Mile	Standard Deviation of Cost per Mile	Median Cost per Mile
39	$4,000	$200,000	$34,090	39,958	$22,059

For comparison, we also looked at the cost of road decommissioning for projects in the original CHRPD database from 3/14/05 (Table77). Cost data in the CHRPD are recorded at the project level. To attempt to get accurate values of cost of road decommissioning, we limited the projects to those with only one task (road decommissioning), one measurement type, and one site per project. We also only looked at projects that began in 1998 or later. There were only 4 projects meeting these criteria. None of the selected road decommissioning projects from the CHRPD occur in the new database.

Table 77. Summary of road decommissioning cost data from the CHRPD (3/14/05). Sites are limited to projects since 1997 with only one task, one measurement type, and one site per project.

Number of Sites	Unit	Minimum Cost per Unit	Maximum Cost per Unit	Average Cost per Unit	Standard Deviation of Cost per Unit
3	mile	$163,883	$509,968	$285,245	194,824
1	acre	$335	$335	$335	

Analysis

As was mentioned above, the new data that we collected from contractors included 52 sites with data for road decommissioning, from 21 different projects. Most statistical analyses require independence of samples, and clearly samples from the same project are not independent. So, for statistical analyses we randomly selected one site from each project and used this subset of the data for our analyses. Cost values are reported here as cost per site, cost per stream crossing treated and cost per mile decommissioned (see Tables74-76).

According to Coffin (2000), factors important to estimating cost of road decommissioning include:

- Land ownership
- Location of project relative to equipment and labor
- Length of road to be decommissioned
- Number of segments and proximity to one another
- Number of stream crossings
- Depth of fill at all culverts
- Type of road construction
- Geology/landform stability/past failures from road system
- Cost of past decommissions in the area

Land Ownership

According to Coffin (2000), projects on National Forest lands and particularly in areas managed under the Northwest Forest Plan are especially costly because of the large number of surveys and extensive environmental documentation required relative to other areas. We used forest service administrative boundaries from the USDA Forest Service to determine, using GIS, which sites occur on National Forest land.

There was a marginally significant difference in log-transformed cost between sites that are on National Forest lands and those that are not (Wilcoxon rank sum test, W = 69, P = 0.066; Figure 69), with cost on National Forest lands being higher.

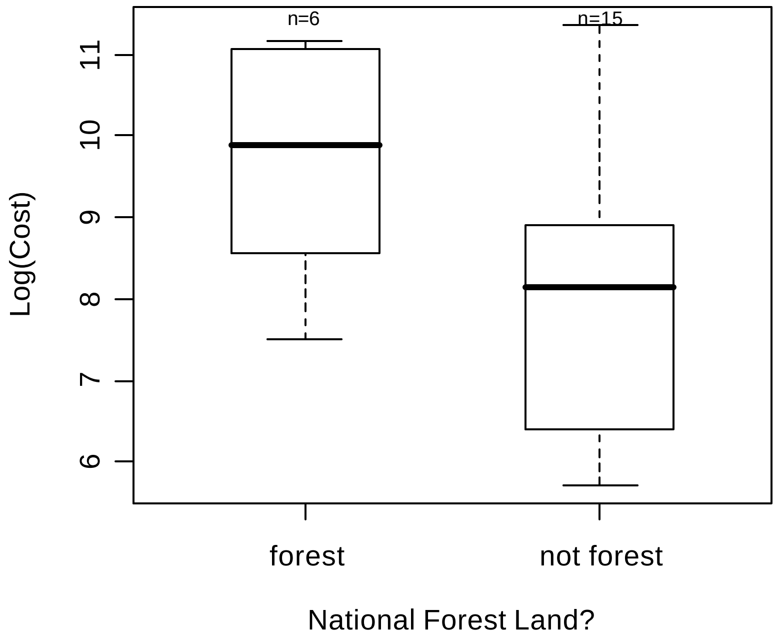

Figure 69. Boxplot of log(cost) for road decommissioning sites from our sample of one site per project that are and are not on National Forest lands.

There was not a significant difference in log-transformed cost per mile between sites that are on National Forest lands and those that are not (Wilcoxon rank sum test, P = 0.73; Figure 70). Decommissioning sites that are on National Forest lands were significantly larger than those that are not (Wilcoxon rank sum test, W = 60.5, p-value = 0.0063; Figure 71).

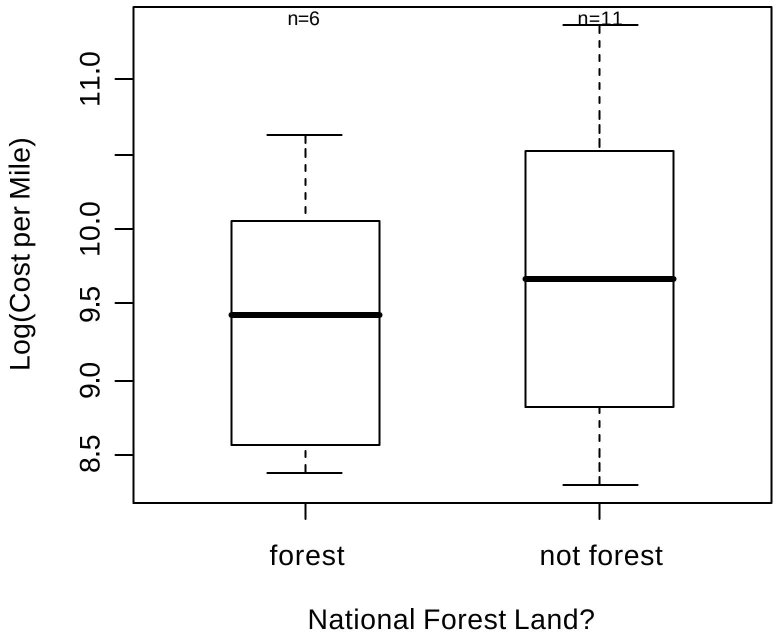

Figure 70. Boxplot of log(cost per mile) for road decommissioning sites from our sample of one site per project that are and are not on National Forest lands.

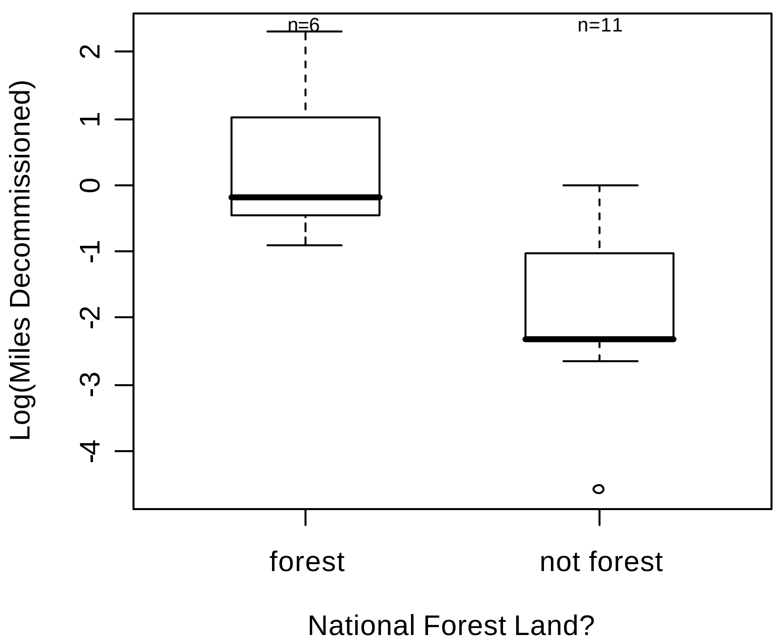

Figure 71. Boxplot of log(miles decommissioned) for road decommissioning sites from our sample of one site per project that are and are not on National Forest lands.

Location Of Project Relative To Materials And Labor

We asked restoration contractors to provide the distance to material (how far materials needed to be transported to the site). Of the 52 road decommissioning sites, only 20 have distance to materials values provided by contractors. For our sample of one site for each project, only 8 of the 21 sites have information for distance to materials. Distance to materials ranged from 0 to 12 miles. There was not a significant relationship between log-transformed cost and log-transformed distance to materials (Regression, P = 0.76) or between log-transformed cost per mile and log-transformed distance to materials (Regression, P = 0.41).

We used GIS to determine the distance from each site to the nearest urban area as a surrogate for distance to labor. Distance to urban area has a slightly bimodal distribution (Figure 72). Distance to nearest urban area was greater for sites on National Forest lands (Wilcoxon rank sum test, W = 88, P = 0.00015; Figure 73). All of the sites on National Forest lands were more than 20 miles from the nearest urban area.

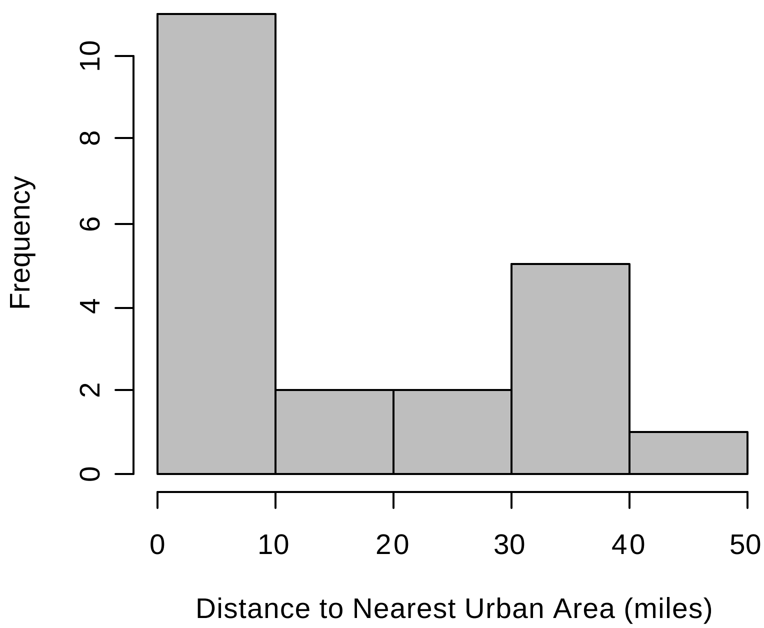

Figure 72. Histogram of distance to nearest urban area.

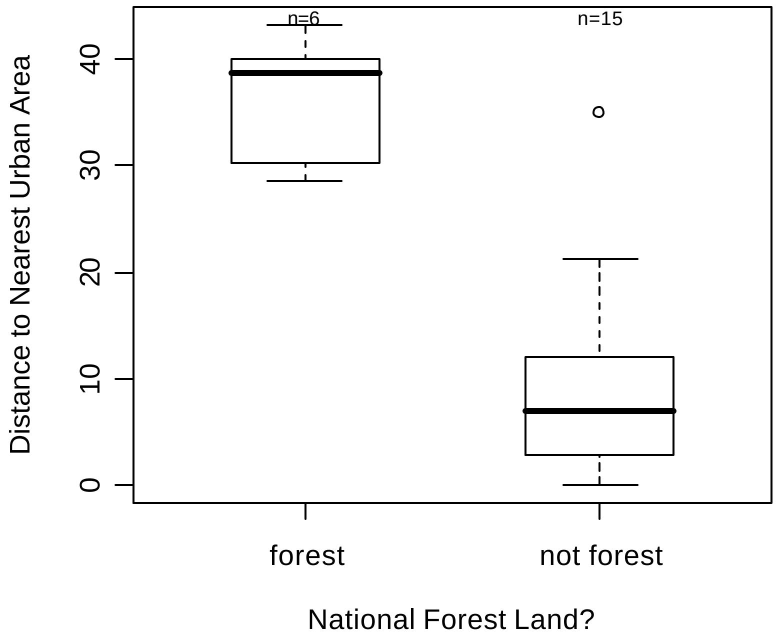

Figure 73. Boxplot of distance to nearest urban area (miles) for sites that are and are not on National Forest lands.

There was not a significant association between distance to the nearest urban area and log-transformed cost of road decommissioning (Regression, P = 0.19; Figure 74) or log-transformed cost per mile (Regression, P = 0.46; Figure 75).

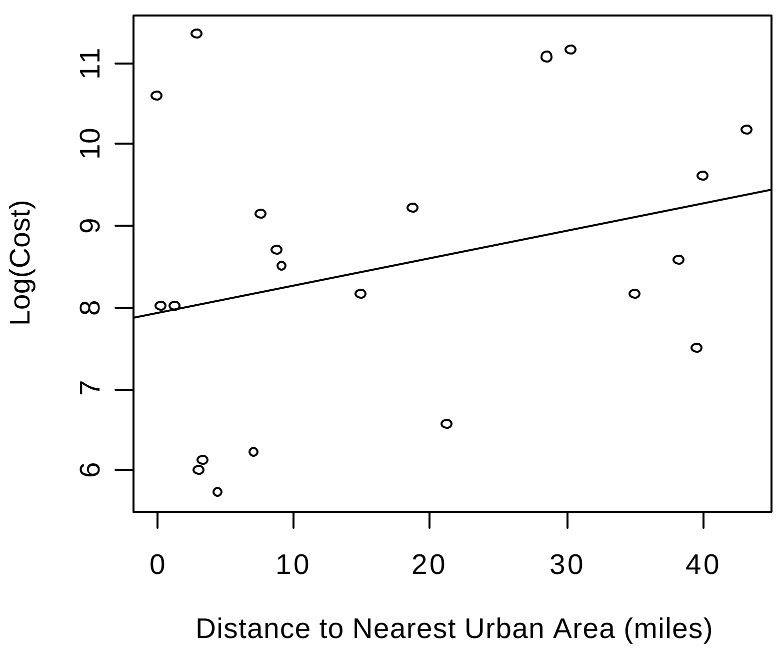

Figure 74. Log(cost) versus distance to nearest urban area (miles) for our sample of one road decommissioning site per project. Line represents least squares fit.

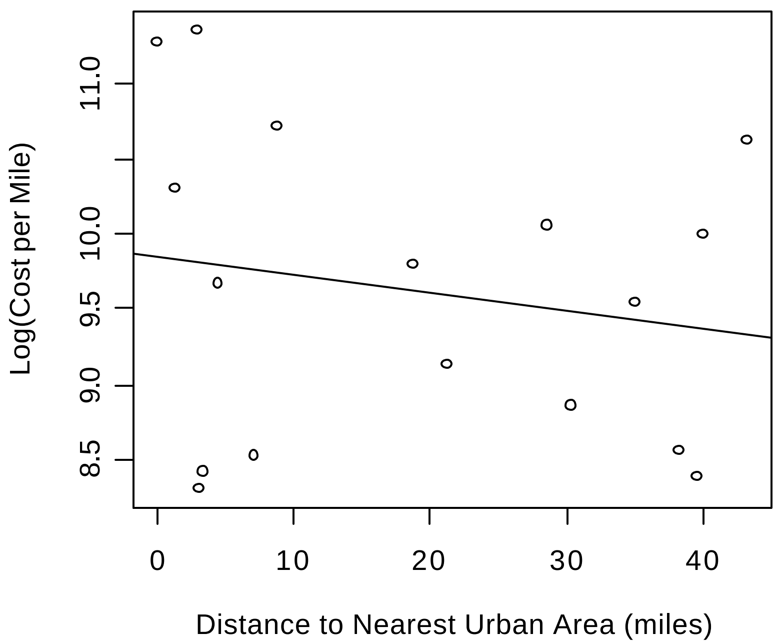

Figure 75. Log(cost per mile) versus distance to nearest urban area (miles) for our sample of one road decommissioning site per project. Line represents least squares fit.

There was a significant positive relationship between the number of miles of road decommissioned (log-transformed) and the number of miles to the nearest urban area (Regression, coef. = 0.051, P = 0.033, R^2adj = 0.22; Figure 76).

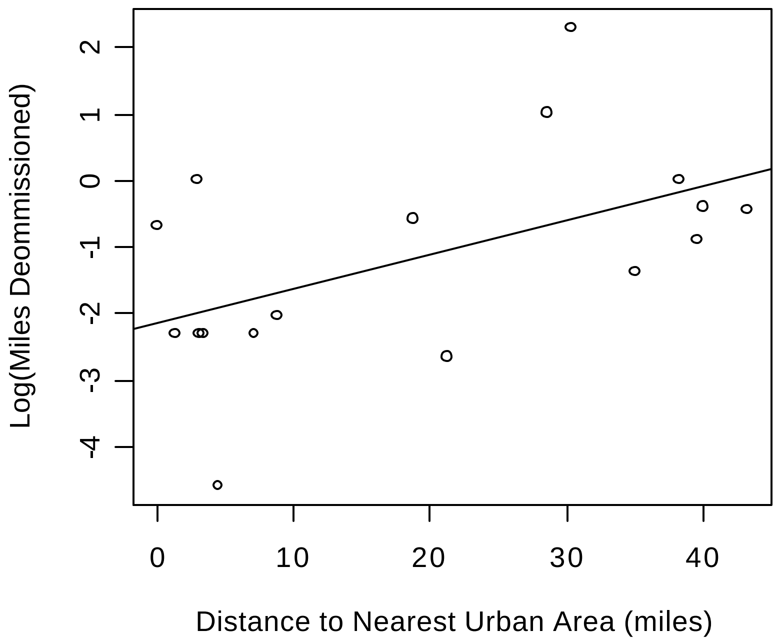

Figure 76. Log(miles decommissioned) versus distance to the nearest urban area (miles) for our sample of one road decommissioning site per project.

Length Of Road To Be Decommissioned

We asked restoration contractors to provide the length of road decommissioned. We received the length of road decommissioned for 39 of the 52 road decommissioning sites. In our sample of one site from each project, 17 of the 21 sites have data on the number of miles decommissioned.

Log-transformed cost was significantly dependent on the log-transformed number of miles decommissioned (Regression, P = 1.67e-05, coef. = 1.03, R^2adj = 0.70; Figure 77). Log transformed cost per mile was not significantly associated with log-transformed number of miles of road decommissioned (Regression, P = 0.59; Figure 78).

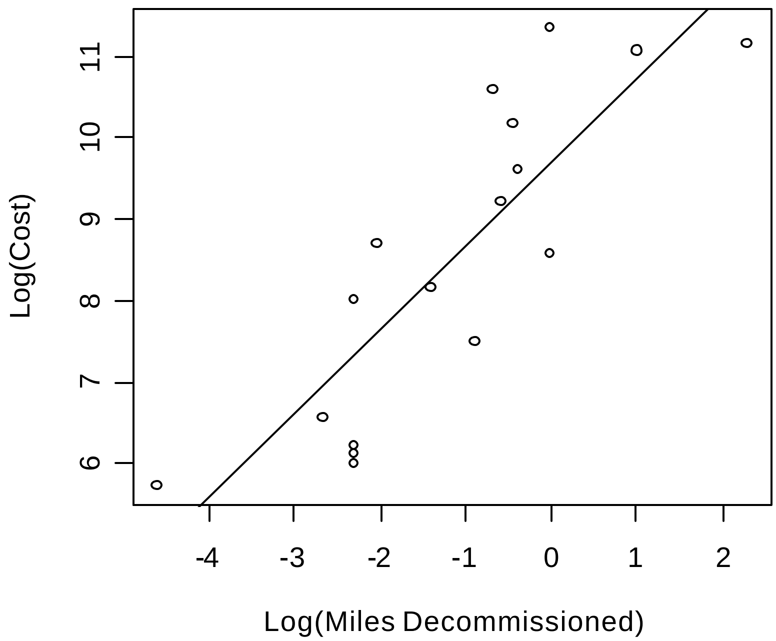

Figure 77. Log(cost) versus log(miles of road decommissioned) for our sample of one road decommissioning site per project.

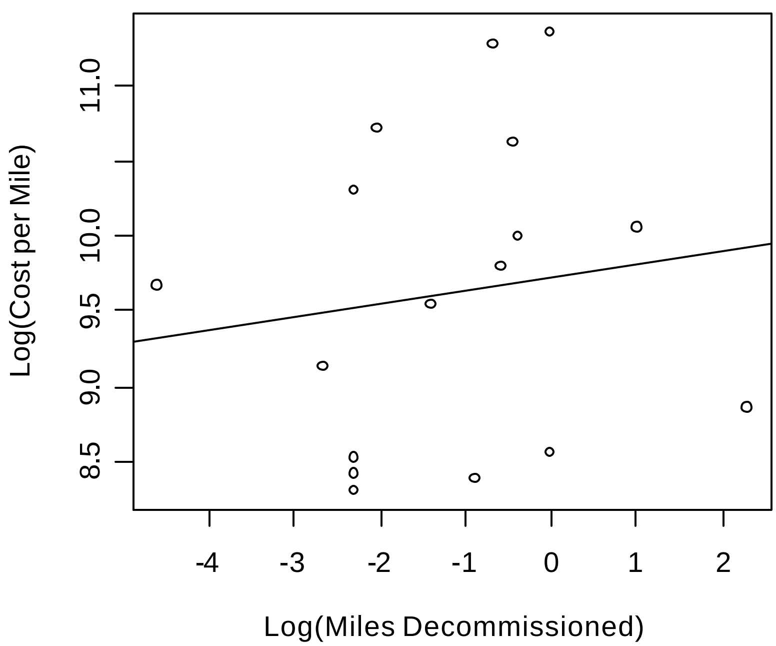

Figure 78. Log(cost per mile) versus log(miles of road decommissioned) for our sample of one road decommissioning site per project.

Number of Segments and Proximity to One Another

There was a significant negative relationship between log-transformed cost per site and log-transformed number of sites per project (Regression, coef. = -0.52, P = 0.047, R^2adj = 0.15; Figure 78), an indication that there may be economies of scale for larger road decommissioning projects. There was, however, also a significant negative association between log-transformed miles decommissioned per site and log-transformed number of sites per project (Regression, coef. = -0.56, P = 0.28, R^2adj = 0.23; Figure 80). The relationship between cost per site and number of sites per project could, therefore, be an artifact of how projects were partitioned into sites.

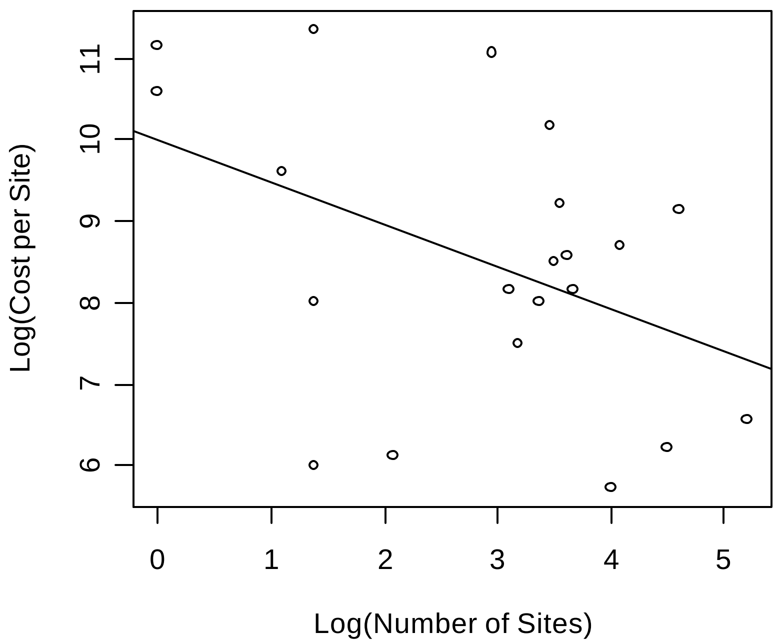

Figure 79. Log(cost) versus log(number of sites per project) for our sample of one road decommissioning site per project.

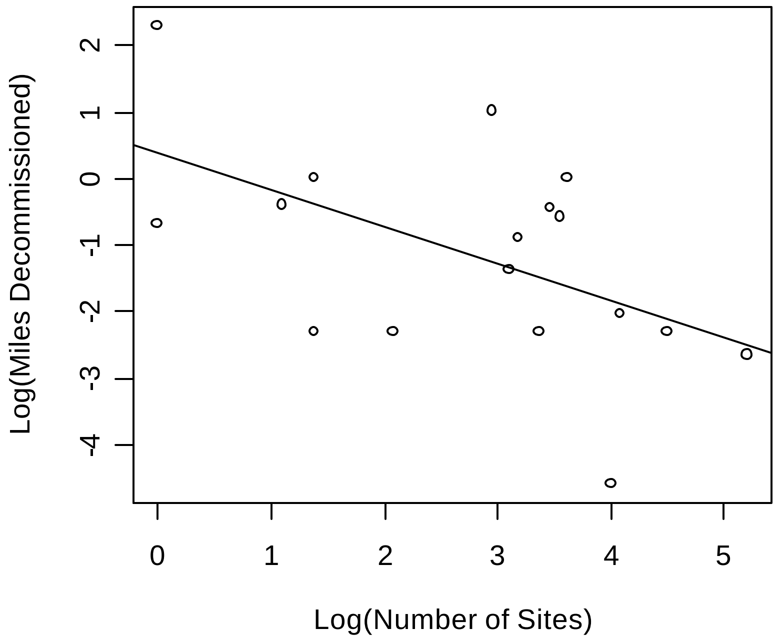

Figure 80. Log(miles decommissioned per site) versus log(number of sites per project) for our sample of one road decommissioning site per project.

There was not a significant relationship between log-transformed cost per mile and log-transformed number of sites per project (Regression, P = 0.49; Figure 81).

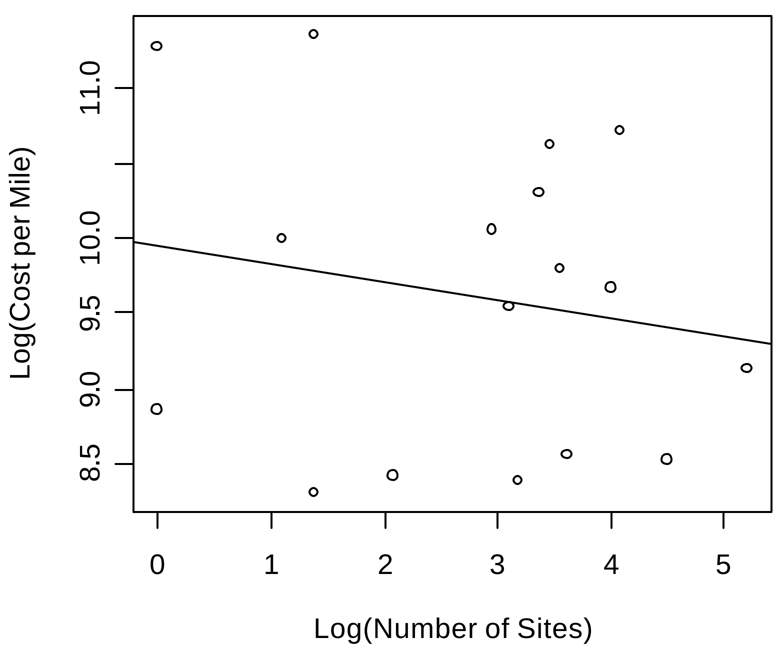

Figure 81. Log(cost per mile) versus log(number of sites per project) for our sample of one road decommissioning site per project.

We used GIS to calculate the average distance between sites in the same project. There was not a significant relationship between log-transformed cost and average distance between sites in the project (Regression, P = .967; Figure 82). The relationship remained non-significant when controlling for the log-transformed number of miles decommissioned (Regression, P = 0.50). There also was not a significant association between log-transformed cost per mile of road decommissioned and log-transformed average distance among sites per project (Regression, P = 0.56).

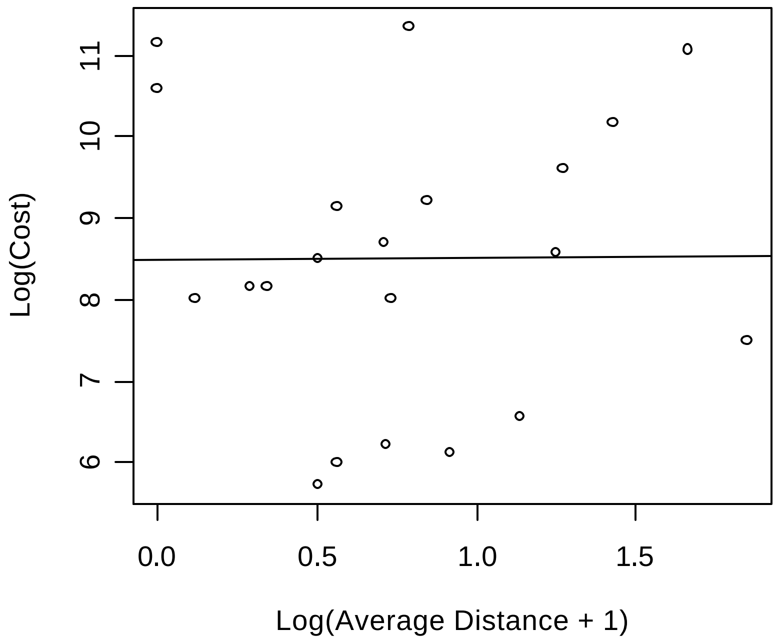

Figure 82. Log(cost) versus log(average distance between sites +1) for our sample of one road decommissioning site per project.

Number of Stream Crossings

We asked restoration contractors to provide the number of stream crossings for each site decommissioned. We received stream crossings data for 47 of the 52 sites (Tables 78 and 79). Of the 21 sites in our sample of one site from each project, all but one site have data on the number of stream crossings.

Table 78. Cost of road decommissioning by number of stream crossings for the complete dataset.

Number of Stream Crossings	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost
0	7	$600	$40,000	$11,782	13,862
1	22	$300	$17,060	$4,430	5,057
2	2	$523	$3,688	$2,106	2,238
3	1	$3,485	$3,485	$3,485	
4	1	$23,670	$23,670	$23,670	

Number of Stream Crossings	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost
5	2	$10,100	$26,277	$18,189	11,439
6	2	$10,000	$77,907	$43,954	48,018
9	2	$12,613	$15,000	$13,807	1,688
11	3	$5,210	$85,806	$38,672	42,001
12	2	$17,000	$60,636	$38,818	30,855
13	1	$64,660	$64,660	$64,660	
17	1	$14,876	$14,876	$14,876	
80	1	$70,000	$70,000	$70,000	

Table 79. Cost per crossing of road decommissioning by number of stream crossings for the complete dataset.

Number of Stream Crossings	Number of Sites	Minimum Cost per Crossing	Maximum Cost per Crossing	Average Cost per Crossing	Standard Deviation of Cost per Crossing
1	22	$300	$17,060	$4,430	5,057
2	2	$262	$1,844	$1,053	1,119
3	1	$1,162	$1,162	$1,162	
4	1	$5,918	$5,918	$5,918	
5	2	$2,020	$5,255	$3,638	2,288
6	2	$1,667	$12,985	$7,326	8,003
9	2	$1,401	$1,667	$1,534	188
11	3	$474	$7,801	$3,516	3,818
12	2	$1,417	$5,053	$3,235	2,571
13	1	$4,974	$4,974	$4,974	
17	1	$875	$875	$875	
80	1	$875	$875	$875	

Eliminating the two sites with no stream crossings, there was a significant positive association between log-transformed cost per site and log-transformed number of stream crossings per site (Regression, coef = 1.061, P = 0.00016, R^2adj = 0.58; Figure 83). There was not a significant association between log-transformed cost per mile and log-transformed number of stream crossings treated (Regression, P = 0.48). Log-transformed number of stream crossings was significantly dependent on the log-transformed number of miles decommissioned (Regression, coef = 0.73, P = 1.37e-06, R^2adj = 0.86; Figure 84).

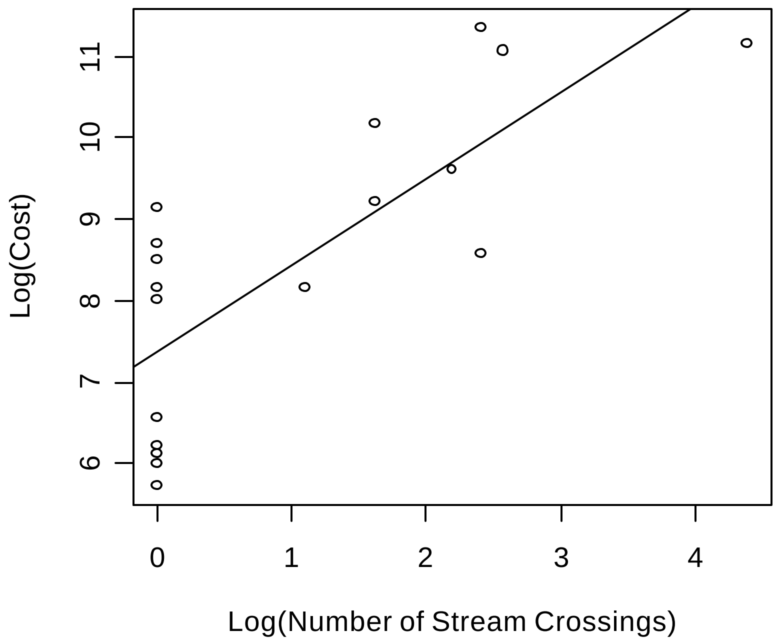

Figure 83. Log(cost) versus log(number of stream crossings treated per site) for our sample of one road decommissioning site per project. The two sites with no stream crossings were removed.

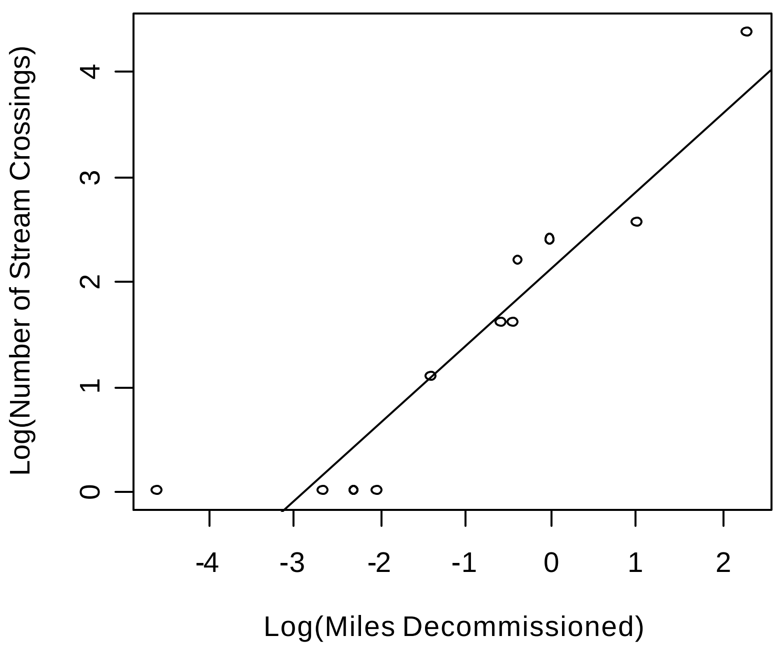

Figure 84. Log(number of stream crossings) versus log(number of miles decommissioned for our sample of one road decommissioning site per project. Sites without stream crossings were removed.

Depth of Fill at Culverts

We did not initially ask restoration contractors to provide information about the amount of fill excavated, but some contractors provided this information on our forms, so we asked others to provide this information as well in follow-up questions after the initial forms were received. We received data on the amount of fill excavated for 41 of the 52 road decommissioning sites and for 16 of the 21 sites in our sample of one road decommissioning site per project.

There was a marginally significant association between log-transformed cost and log-transformed amount of fill excavated (Regression, coef = 0.42, P = 0.085, R^2adj = 0.14; Figure 85), and there was a marginally significant association between log-transformed cost per crossing and log-transformed amount of fill excavated (Regression, coef = 0.32, P = 0.071, R^2adj = 0.18; Figure 86). There was not a significant association between cost per mile of road decommissioning and amount of fill excavated (Regression, P = 0.37).

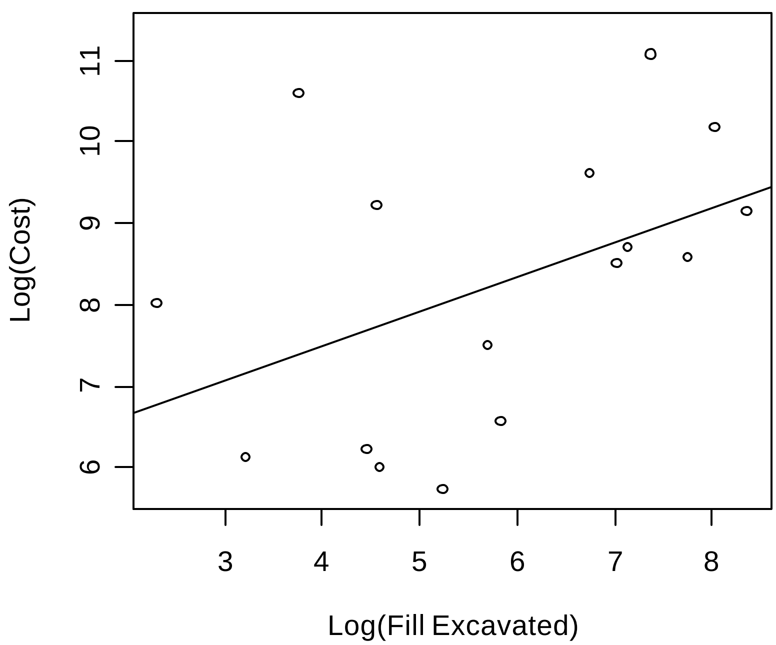

Figure 85. Log(cost) versus log(fill excavated) for our sample of one road decommissioning site per project. Fill excavated is measured in cubic yards.

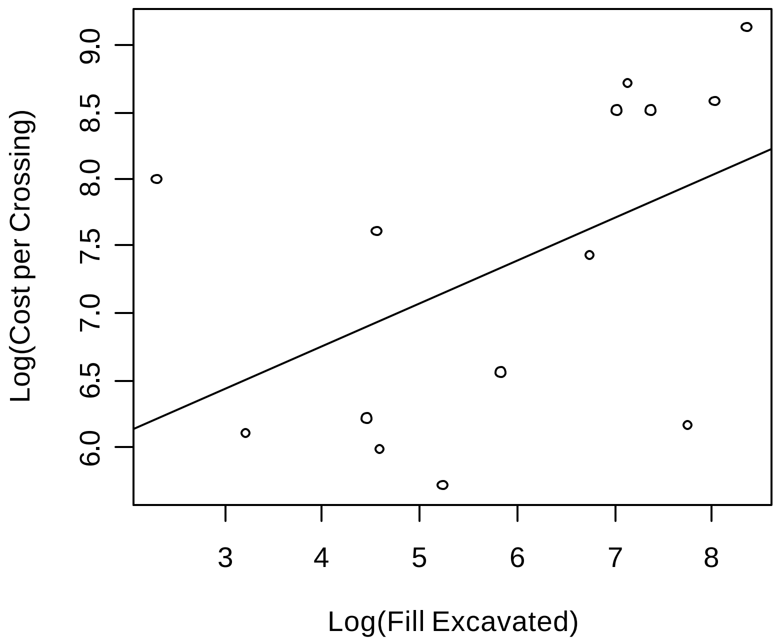

Figure 86. Log(cost per crossing) versus log(fill excavated) for our sample of one road decommissioning site per project.

Type Of Road Construction

Restoration contractors were asked to provide information on the type of road decommissioning:

- closure only = close road to avoid need for regular maintenance, storm-proofing
- partial = hydrologic obliteration
- complete obliteration = full topographic obliteration

We received data on the type of road decommissioning for all 52 road decommissioning sites. Cost data by decommissioning type are shown in Tables 80 and 81.

Table 80. Cost of road decommissioning by type of decommissioning for the complete dataset.

Decommission Type	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
closure only	1	$1,790	$1,790	$1,790		$1,790
partial	36	$300	$77,907	$14,402	21,352	$ 4,805
complete obliteration	15	$400	$85,806	$12,985	21,331	$ 4,958

Table 81. Cost per mile of road decommissioning by type of decommissioning for all sites with number of miles decommissioned reported.

Decommission Type	Number of Sites	Minimum Cost per Mile	Maximum Cost per Mile	Average Cost per Mile	Standard Deviation of Cost per Mile	Median Cost per Mile
closure only	1	$4,366	$4,366	$4,366		$4,366
partial	31	$4,799	$200,000	$36,538	42,686	$ 23,005
complete obliteration	7	$4,000	$85,806	$27,492	27,802	$ 22,059

Log-transformed cost did not differ significantly among the different types of road decommissioning (Kruskal-Wallis, chi-squared = 1.23, df = 2, P = 0.54; Figure 87). Log-transformed cost per mile also did not differ significantly among the different types of road decommissioning (Kruskal-Wallis chi-squared = 2.096, df = 2, p-value = 0.35; Figure 88).

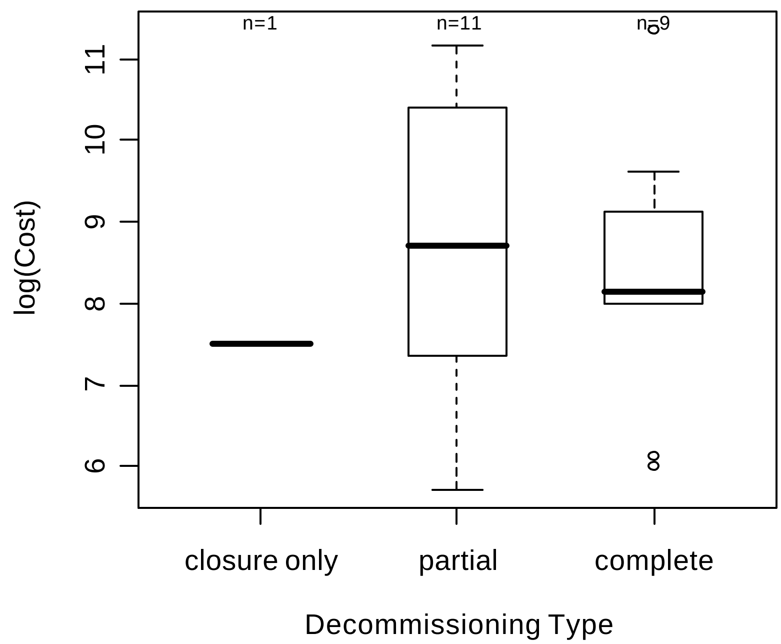

Figure 87. Boxplot of log(cost) for each type of road decommissioning for our sample of one road decommissioning site per project.

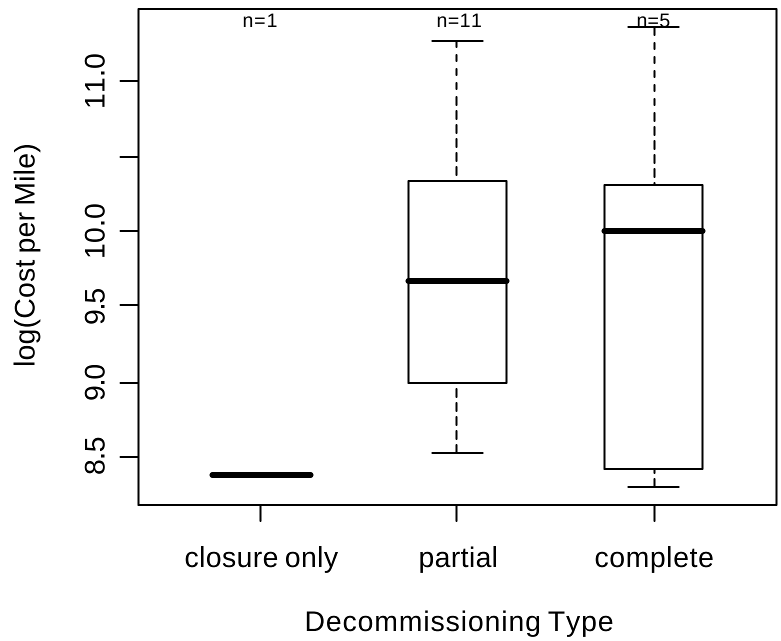

Figure 88. Boxplot of log(cost per mile) for each type of road decommissioning for our sample of one road decommissioning site per project.

Geology/Landform Stability/Past Failures From Road System

We do not have specific information about the past failures from the various road systems. Lacking this, we used general information on average site slope derived from USGS 30 meter National Elevation Data (NED) using GIS and information on soil erodibility from a database containing hydrology-relevant soils information from the United States Geological Survey (USGS) Water Resources Section. The soils data are based on State coverages from the October 1994 State Soil Geographic (STATSGO) CD-ROM database, issued by the U.S. Department of Agriculture.

We calculated slope from the USGS 30 meter NED using the Slope function in ArcGIS software (ESRI,2005). The slope values for all cells intersecting the site were averaged to arrive at an average slope for each site. We used KFFACT (the actual k factor used in the water erosion component of the universal soil loss equation) from the USGS soils database as an estimate of soil erodibility. The weighted average KFFACT value for soils polygons intersecting the site was calculated to arrive at an average soil erodibility for each site. Each soil k factor was weighted by the proportion of the site it represents. Both of these estimates are very coarse and do not take into account localized site-level characteristics.

There was not a significant association between log-transformed cost and slope (Regression, P = 0.34; Figure 89). There was still not a significant association between cost and slope when controlling for the number of miles decommissioned (Regression, P = 0.15). There was also not a significant association between cost per mile of road decommissioning and slope (Regression, P = 0.24; Figure 90). For both of these tests, there was a significant increase in variability in cost with increasing slope. There was no association between cost or cost per mile and the weighted average soils k factor for the site.

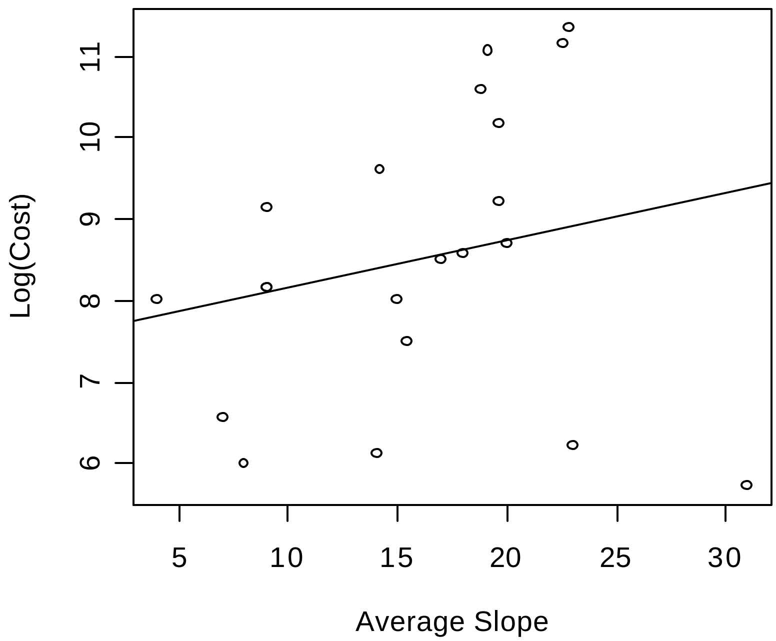

Figure 89. Log(cost) versus average slope for our sample of one road decommissioning site per project.

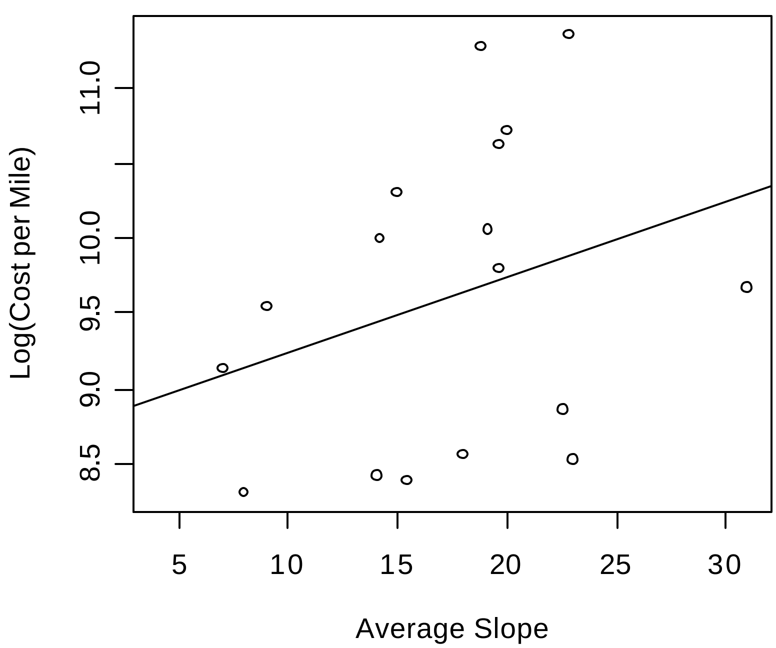

Figure 90. Log(cost per mile) versus average slope for our sample of one road decommissioning site per project.

Cost Of Past Decommissions In The Area

We did not collect data on the cost of past road decommissioning projects in each area.

Labor Cost

As a surrogate for labor costs, we collected information on unemployment rates and construction salaries from the California Employment Development Department (CalEDD) and Rand California respectively. Unemployment rates are county level Labor Force Data from the Labor Market Information Division of the CalEDD. Average annual construction wages are for 'Heavy and Civil Engineering Construction' from the Covered Employment and Wages (CEW) program of the Bureau of Labor Statistics but were acquired from Rand California. Data from both datasets are at the county level and were assigned to sites based on the county associated with the site and the year the project began. When sites overlapped multiple counties, the data were assigned to sites based on a weighted average of how much of each site occurs within each county. Some sites are missing construction wage data because data are not available for all counties for each year.

Controlling for the log-transformed number of miles decommission, there was a significant negative effect of average unemployment rate on log-transformed cost (Regression, coef. = -26.77, P = 0.032; Table 82). There was a marginally significant negative association between average unemployment rate and log-transformed cost per mile of road decommissioning (Regression, coef = -21.70, P = 0.056, R^2adj = 0.17; Figure 91).

Table 82. Regression coefficients, response = log(cost), overall R^2adj = 0.77, P = 0.000013.

	Estimate	Standard Error	t value	Pr(>|t|)
(Intercept)	11.6623	0.8732	13.356	2.34e-09
Average Unemployment Rate	-26.7652	11.2606	-2.377	0.0323
Log(Miles Decommissioned)	1.1657	0.1557	7.486	2.94e-06

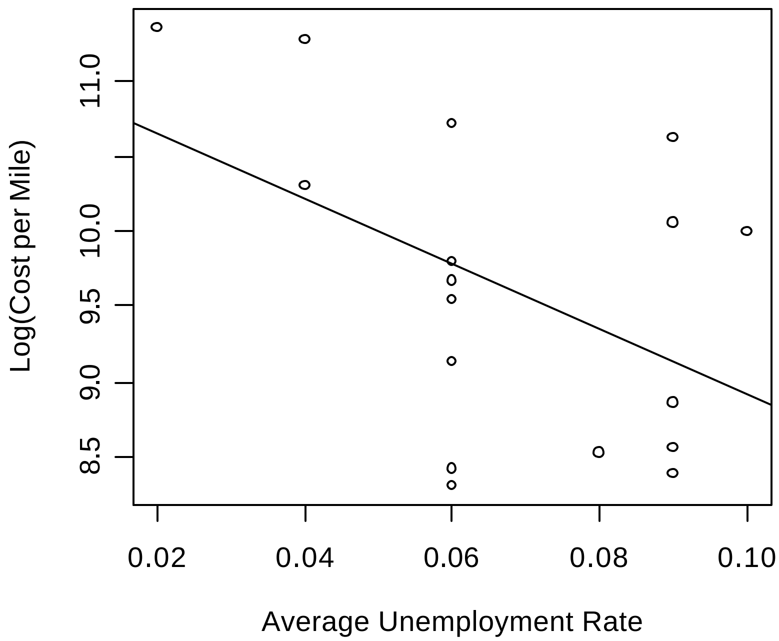

Figure 91. Log(cost per mile) versus average annual unemployment rate for our sample of one road decommissioning site per project.

Controlling for the log-transformed number of miles decommissioned, there was a significant positive effect of average annual construction wages ($1,000s) on log-transformed cost of road decommissioning (Table 83). There was not a significant association between average annual construction wages and log-transformed cost per mile (Regression, P = 0.25; Figure 92).

Table 83. Regression coefficients, response=log(cost), overall R^2adj = 0.77, P = 0.046.

	Estimate	Standard Error	t value	Pr(>|t|)
(Intercept)	7.074	1.29	5.47	0.00094
Annual Construction Wages ($1,000s)	0.074	0.031	2.42	0.046
Log(Miles Decommissioned)	1.73	0.30	5.71	0.00073

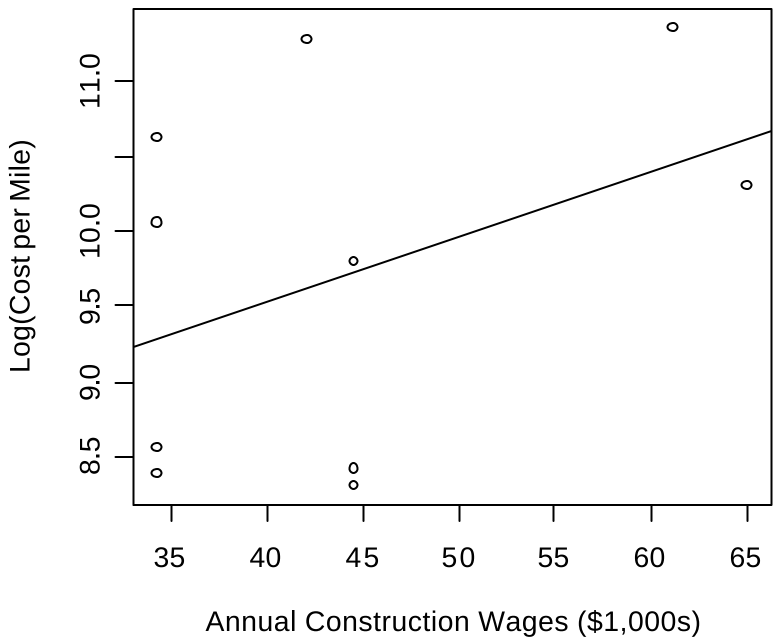

Figure 92. Log(cost per mile) versus average annual construction wages for our sample of one road decommissioning site per project.

Road Decommissioning Analysis Summary

70% of the variability in cost of road decommissioning is explained by the number of miles decommissioned. The more miles of road decommissioned, the higher the cost of the project. The number of stream crossings per site also increases significantly with the number of miles decommissioned, and is also positively associated with cost of road decommissioning. The number of miles of road decommissioned tends to be greater farther from urban areas.

Controlling for the number of miles decommissioned, road decommissionings on sites in counties with higher average unemployment rates tended to cost less than those on sites with lower average unemployment rates, and road decommissionings on sites in counties with higher average annual construction wages tended to cost more than those in counties with lower average annual wages.

Factors that marginally affect cost of road decommissioning projects include whether the site is on national forest land, the total number of sites per project (the more sites per project, the lower the cost per site), and the amount of fill excavated. None of these variables has a significant effect on cost when controlling for the number of miles decommissioned. Number of sites per project was negatively associated with the number of miles per site.

Road Surface Upgrade/Maintenance (excluding culverts)

We received data on 50 sites that included cost information associated with road upgrading. 43 of those included data on the number of miles upgraded. These sites came from 23 different projects. There were between 1 and 8 sites per project (Table 84). Number of sites and cost statistics are reported in Tables 85 and 86.

Table 84. Number of projects by number of sites per project for road upgrading projects.

Number of Sites	Number of Projects
1	11
2	6
3	2
4	2
5	1
8	1

Table 85. Summary of road upgrading cost.

Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost
50	$200	$500,250	$40,575	106,697

Table 86. Summary of road upgrading cost per mile.

Number of Sites	Minimum Cost per Mile	Maximum Cost per Mile	Average Cost per Mile	Standard Deviation of Cost per Mile
43	$1,000	$3,478,947	$168,977	622,606

For comparison, we also looked at the cost of road upgrading for projects in the original CHRPD database from 3/14/05 (Table 87). Cost data in the CHRPD are recorded at the project level. To attempt to get accurate values of cost of road upgrading, we limited the projects to those with only one task (road upgrading), one measurement type, and one site per project. We also only looked at projects that began in 1998 or later. None of the selected road upgrading projects from the CHRPD occur in the new database.

Table 87. Summary of road upgrading cost data from the CHRPD (3/14/05). Sites are limited to projects since 1997 with only one task, one measurement type, and one site per project. Units are the units of measurement recorded in the CHRPD.

Number of Sites	Unit	Minimum Cost per Unit	Maximum Cost per Unit	Average Cost per Unit	Standard Deviation of Cost per Unit
7	mile	$1,944	$47,389	$15,209	17,654
3	culvert	$1,058	$7,827	$4,497	3,386
1	unit	$11,399	$11,399	$11,399	
1	cubic yard	$15	$15	$15	
1	crossing	$2,329	$2,329	$2,329	
1	acre	$9,617	$9,617	$9,617	

Analysis

As was mentioned above, the new data that we collected from contractors included 50 sites with cost information from 23 different projects. Most statistical analyses require independence of samples, and clearly samples from the same project are not independent. So, for statistical analyses we randomly selected one site from each project and used this subset of the data for our analyses.

According to Weaver and Hagans (2000), factors important to estimating cost of road upgrading, decommissioning, and maintenance projects include:

- Maintenance status of road (open or abandoned/overgrown or washed out)
- Type of road (commercial, ranch, residential, public, etc)
- Inventory, prescription and layout costs
- Assessment and prescription "accuracy" (experience of personnel)
- Heavy equipment and laborer experience in comparable work
- Storm-proofing design specifications
- Stream crossing design standards
- Secondary erosion control treatments required (e.g. channel or fill slope armoring)
- Equipment availability and equipment used
- Equipment rental rates (including operator and fuel)
- Surfacing requirements and availability (costs for rock or paving)
- Site frequency
- Stream crossing frequency
- Connectivity of road surface with stream channels
- Supervision requirements
- Site volume (volume excavated)
- Endhaul volume
- Endhaul distance
- Layout requirements (staking or descriptive specifications)
- Contracting method (hourly or bid)
- Overhead

These cost factors are very specific factors for projects that are planned with detailed ground assessments. The goal of this study is to try to determine more general factors for predicting costs. For this reason we use the more general categories below, some of which correspond roughly to one or more of the above cost factors.

Upgrade Type

We asked restoration contractors to provide the type of upgrade that was performed at the site: outsloping/insloping/crowning; ditch relief culverts (drc); rolling dips; waterbars; resurfacing; or other. There were no sites with outsloping/insloping/crowning as the sole upgrade type, and there were 17 sites with multiple road upgrade types. The number of sites with each type of upgrade is shown in Table 88. Of the 17 sites with multiple upgrade types, 6 had both outsloping and rolling dips. We created a separate category for these sites. The descriptions given by contractors for the type of upgrade in the 'other' category are shown in Table 89. Table 90 summarizes costs for sites with multiple road upgrade types. The cost of road upgrading by type of upgrade is summarized in Tables 91 and 92.

Table 88. Number of sites by upgrade type for road upgrade projects from the complete dataset.

Upgrade Type	Number of Sites
rolling dips	19
Multiple	17
Other	7
ditch relief culverts	4
resurfacing	3

Table 89. Description and cost of road upgrade from the 'other' category

'Other' Upgrade Type	Cost
Rocked Dip	$470
Sidecast Excavation	$1,585
Rocked Ford	$1,661
Wet crossing	$6,610
Unstable fill excavation - 302 cubic yards	$500
Grading	$500
Fillslope excavation - 444 cubic yards	$2,100

Table 90. Summary of cost information for sites with multiple types of road upgrade.

Upgrade Type	Number of Sites	Average Cost	Minimun Cost	Maximum Cost
Outsloping and rolling dips	6	$283,131	$60,375	$500,250
rolling dips and waterbars	1	$1,000	$1,000	$1,000
Outsloping/insloping/crowning and rolling dips	1	$5,000	$5,000	$5,000
Outsloping/insloping/crowning and resurfacing	1	$5,000	$5,000	$5,000
Outsloping, rolling dips, and other (berm removal and wet crossing installation).	1	$7,163	$7,163	$7,163
outsloping, (2) 18" x 30' ditch relief culverts, 1 rolling dip, 150' road resurfacing.	1	$3,900	$3,900	$3,900
outsloping 450 feet, 2 rolling dips, resurfacing 450 feet.	1	$2,300	$2,300	$2,300
outsloping 365', 2 rolling dips, other: clean/cut ditch, rock road.	1	$2,900	$2,900	$2,900
outsloping 120 feet, resurfacing 120 feet.	1	$517	$517	$517
550' outsloping, 2 rolling dips, 550' resurfacing.	1	$3,650	$3,650	$3,650
525' outsloping, 2 rolling dips, 525' resurfacing, other: remove berm 525'.	1	$3,700	$3,700	$3,700
0.5 miles outsloping, 3 ditch relief culverts, 14 rolling dips, 435 cu.yd. rock resurfacing.	1	$19,246	$19,246	$19,246

Table 91. Road upgrading cost by type of upgrade for the complete dataset.

Upgrade Type	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost
rolling dips	19	$200	$1,660	$749	630
multiple	11	$517	$19,246	$4,943	5,100
other	7	$470	$6,610	$1,918	2,173
outsloping and rolling dips	6	$60,375	$500,250	$283,131	146,276
ditch relief culverts	4	$650	$5,235	$2,771	1,910
resurfacing	3	$1,600	$226,862	$78,954	128,137

Table 92. Road upgrading cost per mile by type of upgrade for the complete dataset.

Upgrade Type	Number of Sites	Minimum Cost per Mile	Maximum Cost per Mile	Average Cost per Mile	Standard Deviation of Cost per Mile
rolling dips	16	$3,000	$30,000	$17,535	8,925
multiple	11	$1,218	$139,286	$28,276	39,988
outsloping and rolling dips	6	$33,173	$108,059	$64,909	33,074
ditch relief culverts	4	$6,500	$23,795	$14,241	7,221
resurfacing	3	$12,308	$2,268,620	$907,678	1,198,042
other	3	$1,000	$3,478,947	$1,168,316	2,001,102

There were significant differences in cost among the different upgrade types (Kruskal-Wallis chi-squared = 12.76, df = 5, p-value = 0.026; Figure 93). There were not significant differences in cost per mile among the different road upgrade types (Kruskal-Wallis chi-squared = 7.06, df = 5, p-value = 0.22; Figure 94).

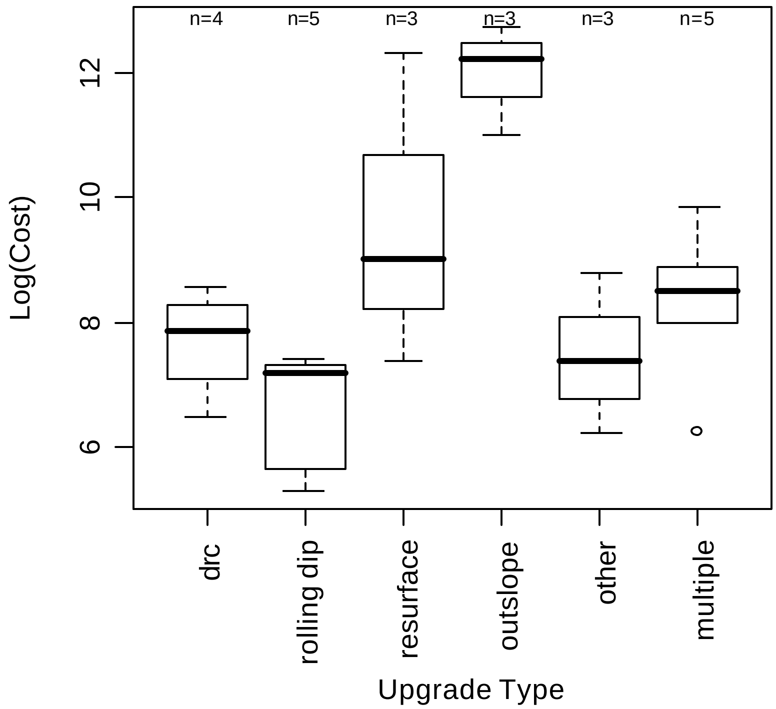

Figure 93. Boxplot of log(cost) for each upgrade type for our sample of one road upgrade site per project.

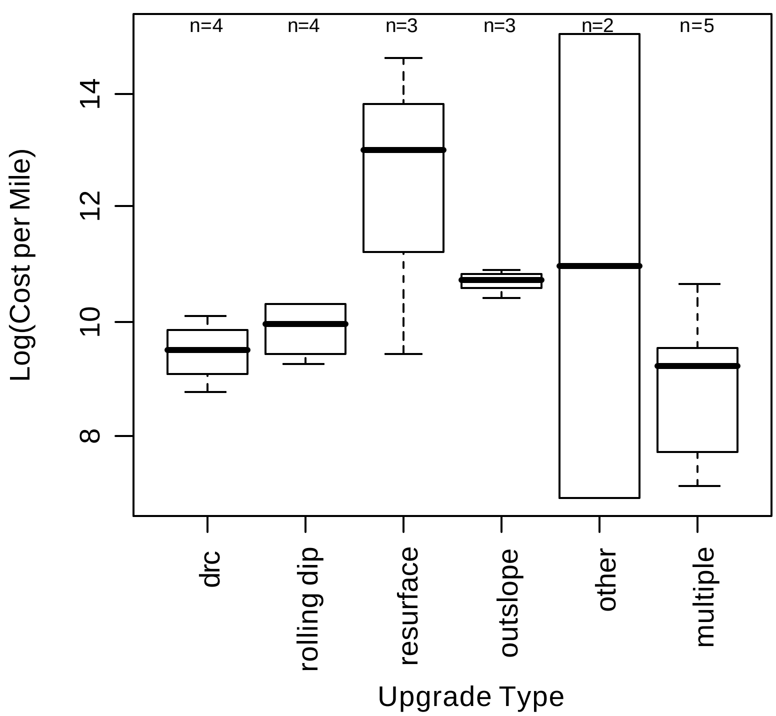

Figure 94. Boxplot of log(cost per mile) for each upgrade type for our sample of one road upgrade site per project.

Miles Upgraded

The number of miles upgraded differed significantly among the different types of road upgrade (Kruskal-Wallis chi-squared = 12.30, df = 5, p-value = 0.031; Figure 95). There was a significant positive relationship between log-transformed cost and log-transformed number of miles upgraded (Regression, coef. = 0.48, P = 0.023, R^2adj = 0.20; Figure 96), but the relationship is somewhat curvilinear. There was a significant negative relationship between cost per mile upgraded and number of miles upgraded (Regression, coef. = -0.48, P = 0.024, R^2adj = 0.20, Figure 97), suggesting the possibility of economies of scale for larger road maintenance/upgrade projects.

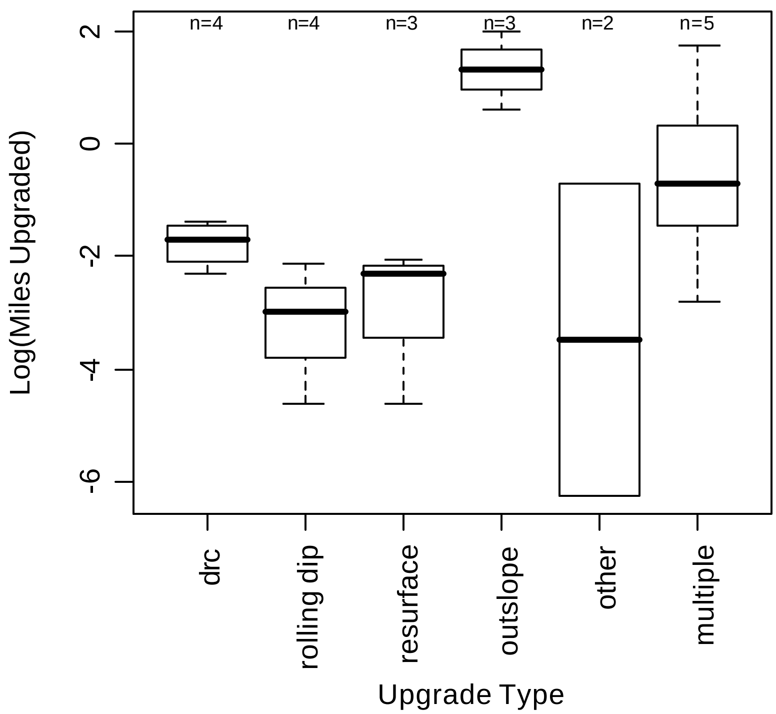

Figure 95. Boxplot of log(miles upgraded) for each upgrade type for our sample of one road upgrade site per project.

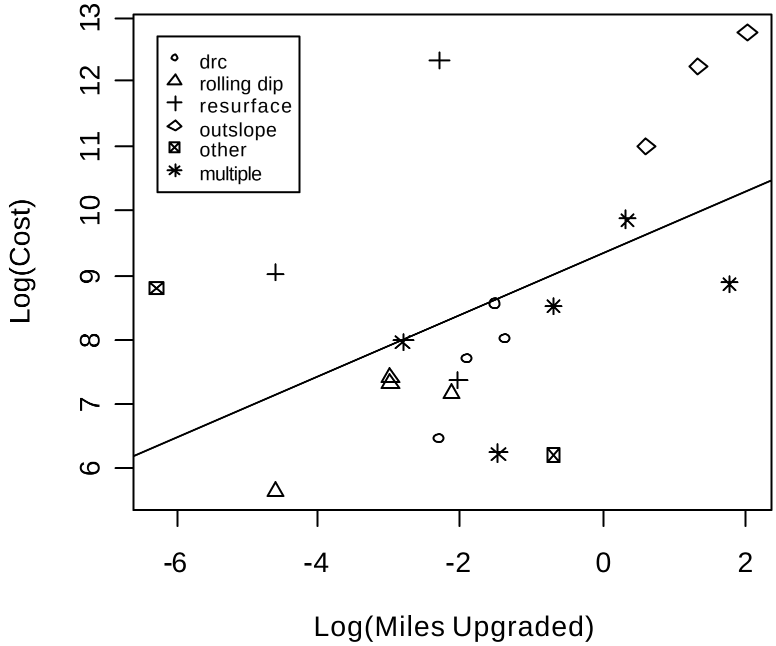

Figure 96. Log(cost) versus log(miles upgraded) for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols.

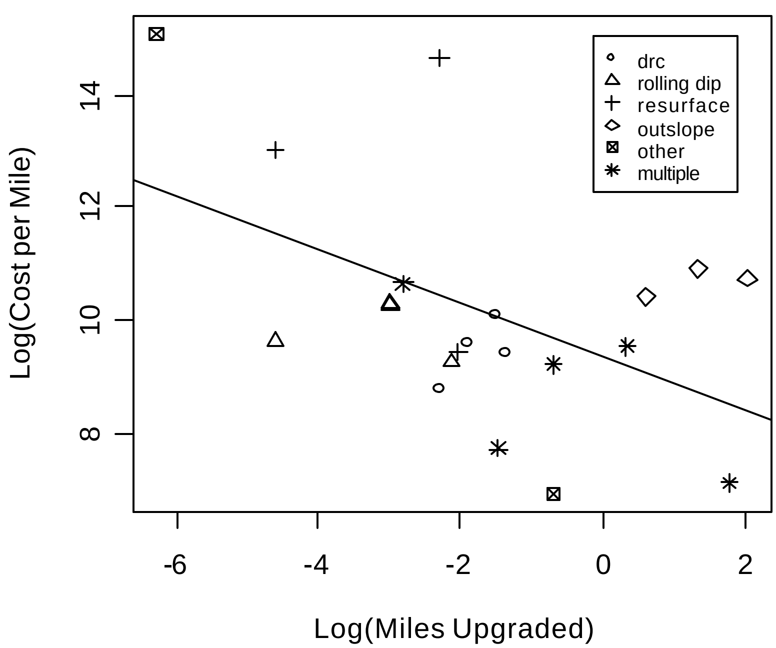

Figure 97. Log(cost per mile) versus log(miles upgraded) for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols.

Site Accessibility

We asked contractors to provide information on the accessibility of the restoration site:

- easy = easy access
- average = partial vehicle access
- difficult = very limited/no vehicle access

We received site accessibility data for 47 of the 50 sites with road upgrade data. All of the sites had easy or average accessibility. For our sample of one road upgrade site for each project, we received site accessibility data for 20 of the 23 sites (Table 93). There were not enough data to evaluate whether site accessibility significantly affects cost for each upgrade type.

Table 93. Road upgrade cost per site and per mile by upgrade type and site accessibility category for our sample of one road upgrade site per project.

Upgrade Type	Site Accessibility	Number of Sites with Cost	Average Cost	Number of Sites with Cost per Mile	Average Cost per Mile	Average Number of Miles Upgraded
drc	easy	4	$2,771	4	$14,241	0.2
rolling dip	easy	4	$1,165	3	$23,174	0.07
rolling dip	average	1	$282	1	$14,921	0.01
resurface	easy	2	$114,231	2	$1,140,464	0.1
resurface	average	1	$8,400	1	$442,105	0.01
outslope	easy	3	$204,955	3	$44,439	4
other	easy	1	$6,610	1	$3,478,947	0.002
other	average	2	$1,043	1	$1,000	0.5
multiple	easy	2	$1,709	2	$22,138	0.2

Grouping all upgrade types, there was not a significant difference in cost between sites with easy and average accessibility (Wilcoxon rank sum test, W = 45, P = 0.25; Figure 98). There was also not a significant difference in cost per mile between sites with easy and average accessibility (Wilcoxon rank sum test, W = 26, P = 0.74; Figure 99). The number of miles upgraded did not differ significantly between sites with easy and average accessibility (Wilcoxon rank sum test, W = 31, P = 0.34; Figure 100).

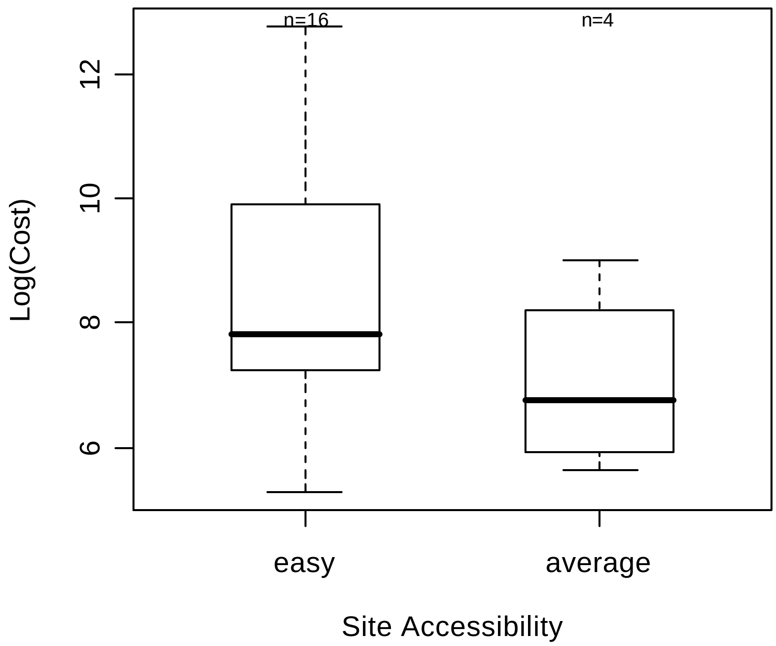

Figure 98. Boxplot of log(cost) for each site accessibility category for our sample of one road upgrade site per project.

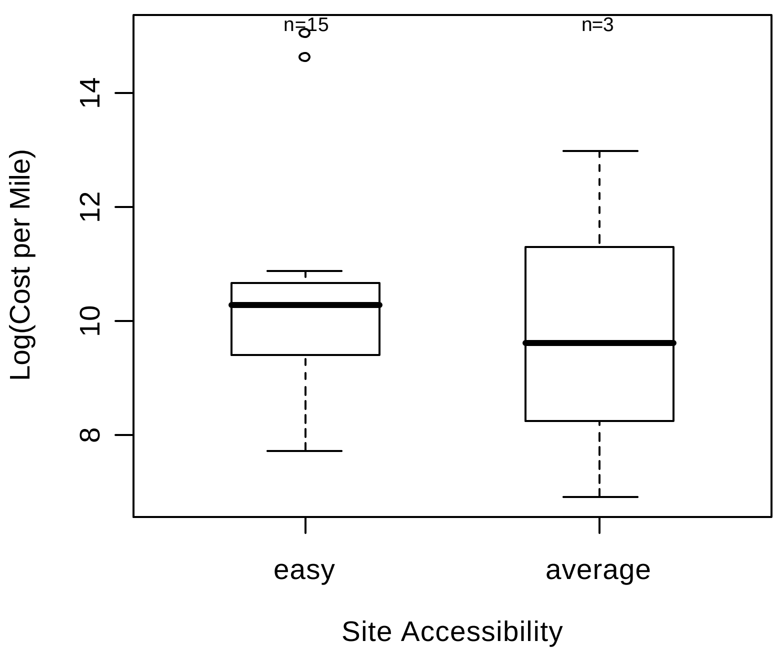

Figure 99. Boxplot of log(cost per mile) for each site accessibility class for our sample of one road upgrade site per project.

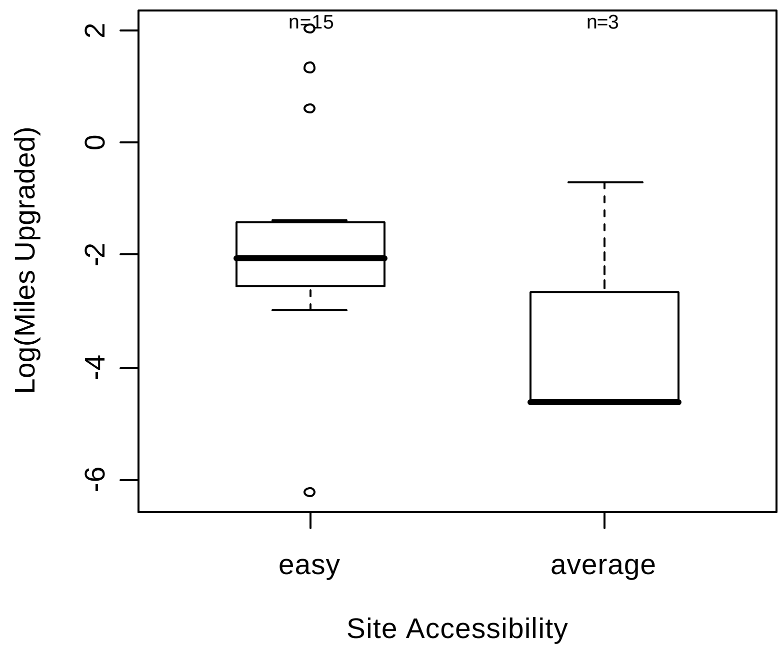

Figure 100. Boxplot of log(miles upgraded) for each site accessibility class for our sample of one road upgrade site per project.

Experience Level of Contractor

Restoration contractors were asked to provide experience level as the approximate number of similar projects the contractor has worked on. We received data on experience level of the contractor for 42 of the 50 road upgrade sites (19 projects). Grouping all of the types of road upgrade, there was not a significant relationship between cost and experience level of the contractor using this measurement (Regression, $P = 0.56$; Figure 101). There was also not a significant relationship between cost per mile of road decommissioning and experience level of the contractor (Regression, $P = 0.19$; Figure 102).

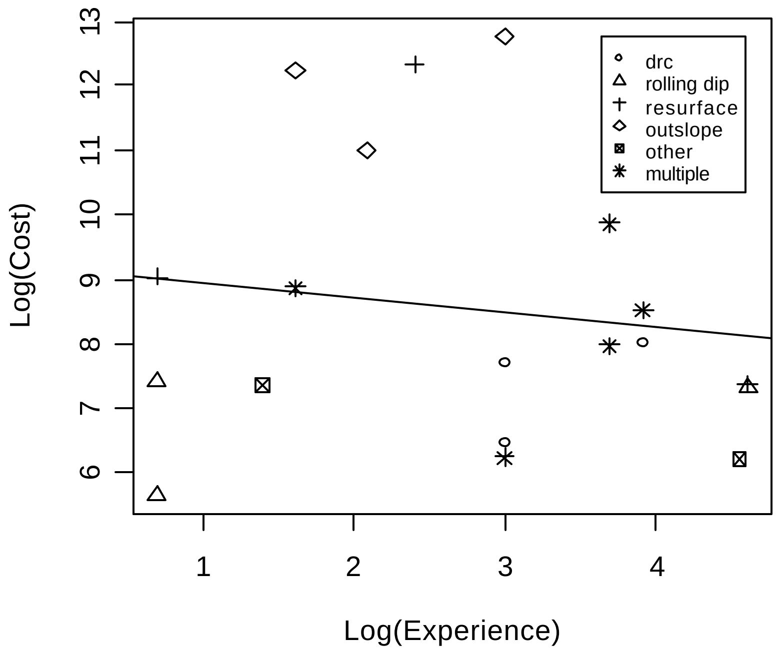

Figure 101. Log(cost) versus log(experience) for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols. Experience is measured as estimated number of similar projects the contractor has worked on.

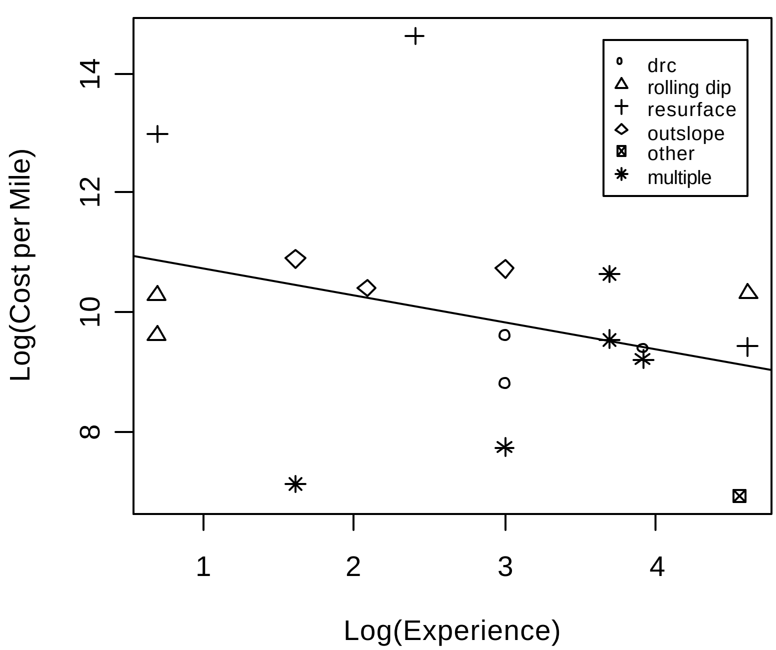

Figure 102. Log(cost per mile) versus log(experience) for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols. Experience is measured as estimated number of similar projects the contractor has worked on.

Distance to Materials

We asked restoration contractors to provide the distance to materials for each site. We received data on the distance to materials for 31 of the 50 road upgrade sites. 5 of these sites had a distance to materials of 0 indicating that no offsite materials were used. Only 14 of the 23 sites from our sample of one road decommissioning site per project have data for distance to materials.

There was not a significant relationship between log-transformed distance to materials and log-transformed cost (Regression, P = 0.20; Figure 103). The relationship remained non-significant when the value of zero for distance to materials was removed (Regression, P = 0.14). There was also not a significant relationship between log-transformed distance to materials and log-transformed cost per mile (Regression, P = 0.27; Figure 104). When the value of zero for distance to materials was removed, there was a marginally significant positive relationship between log-transformed distance to materials and log-transformed cost per mile of road upgrading (Regression, coef. = 0.82, P = 0.052, R^2adj = 0.26; Figure 105).

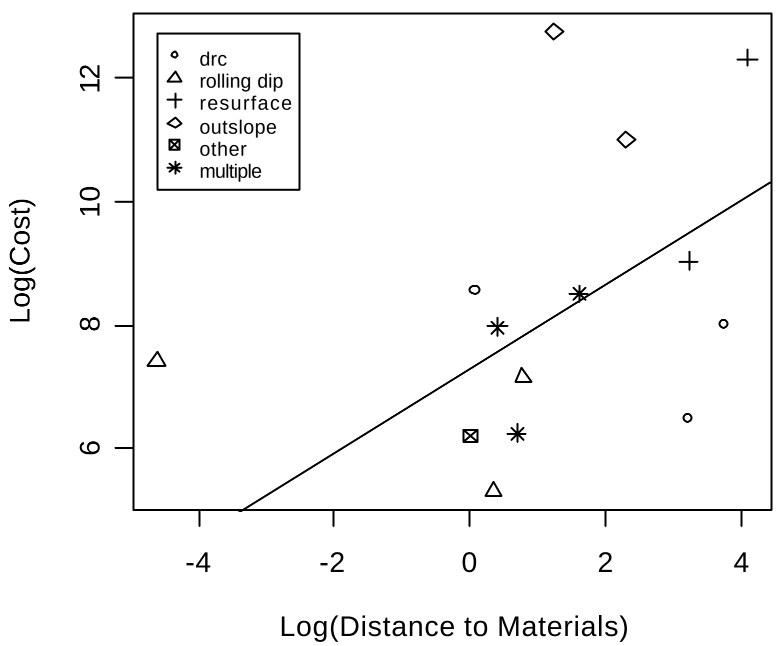

Figure 103. Log(cost) versus log(distance to materials + 0.01) for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols. Distance to materials is measured in miles.

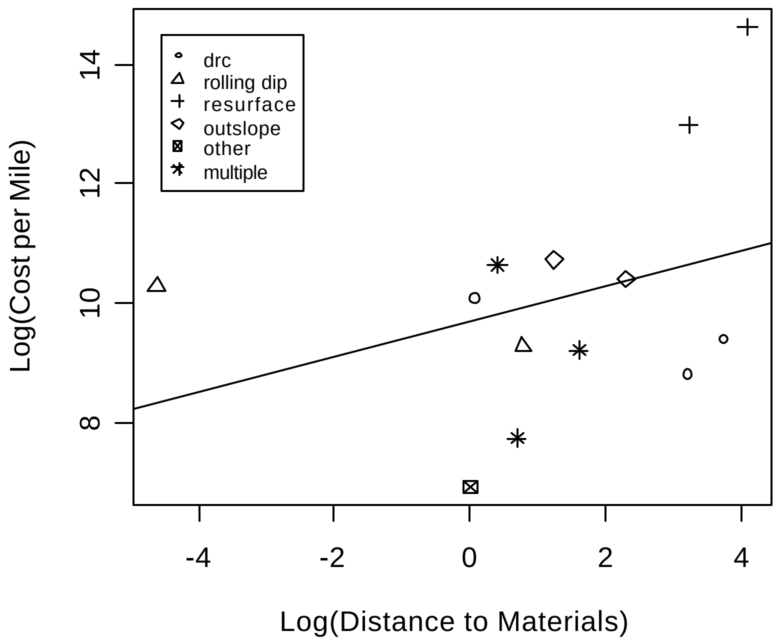

Figure 104. Log(cost per mile) versus log(distance to materials + 0.01) for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols. Distance to materials is measured in miles.

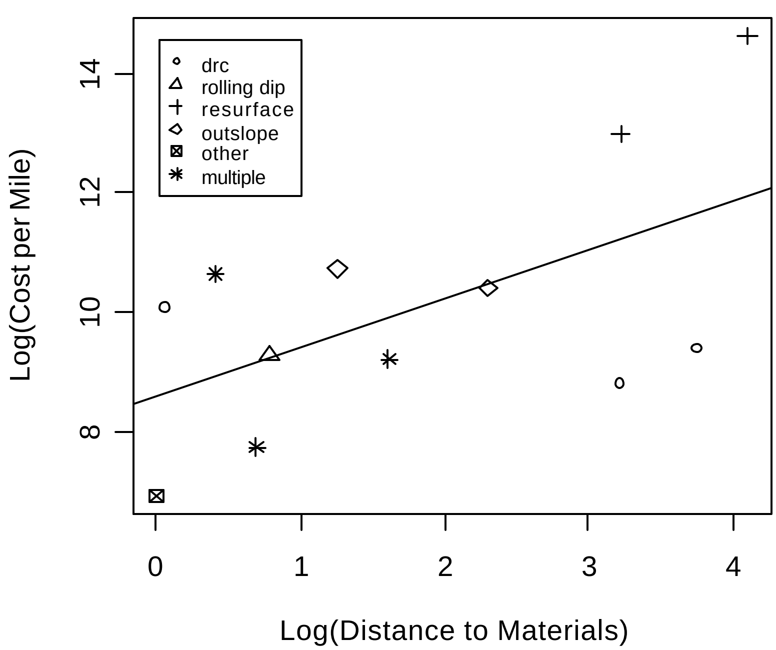

Figure 105. Log(cost per mile) versus log(distance to materials) for our sample of one road upgrade site per project with the value of zero for distance to materials removed. Upgrade types are distinguished by different symbols. Distance to materials is measured in miles.

Distance to Nearest Urban Area (Equipment & Labor Availability)

We used GIS to determine the distance from each site to the nearest urban area as a surrogate for distance to labor. Grouping all upgrade types, there was a significant positive effect of distance to nearest urban area on log-transformed cost (Regression, coef. = 0.086, P = 0.0091, R^2adj = 0.25; Figure 106). There was not a significant relationship between log-transformed cost per mile and distance to nearest urban area (Regression, P = 0.99; Figure 107). Sites further from the nearest urban area tended to have larger road upgrade projects (Regression, coef. = 0.082, P = 0.020, R^2adj = 0.21; Figure 108)

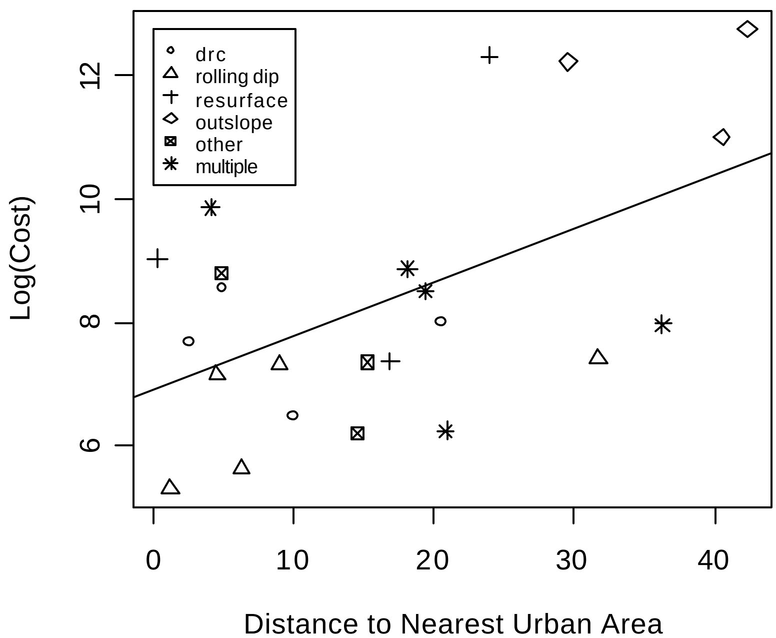

Figure 106. Log(cost) versus distance to nearest urban area for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols. Distance to nearest urban area is measured in miles.

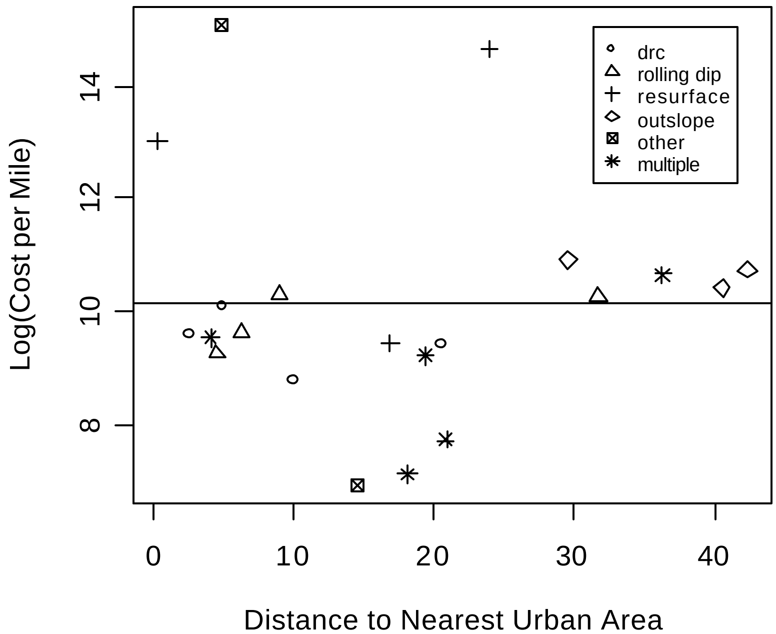

Figure 107. Log(cost per mile) versus distance to nearest urban area for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols. Distance to nearest urban area is measured in miles.

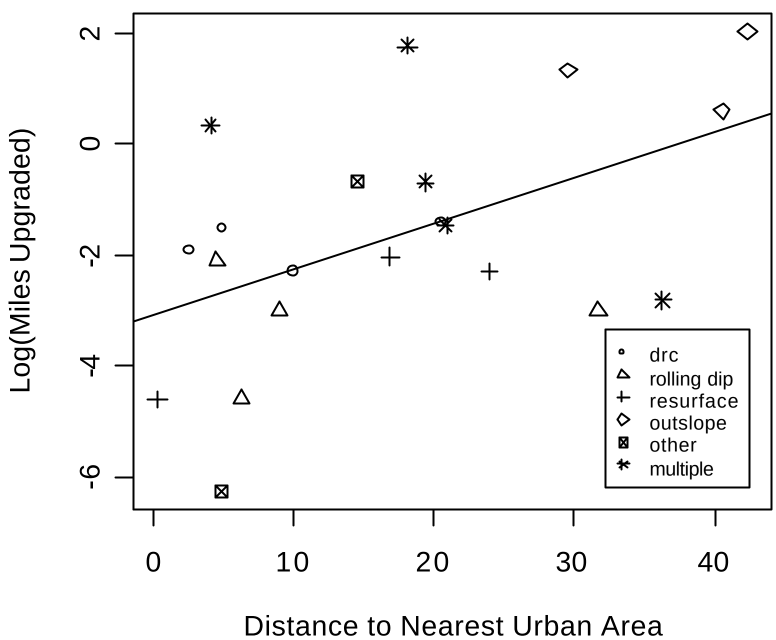

Figure 108. Log(miles upgraded) versus distance to nearest urban area for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols. Distance to nearest urban area is measured in miles.

Stream Crossing Frequency

We did not ask restoration contractors to provide stream crossing frequency for their sites. If all sites were digitized consistently as lines along the road length, it would be possible to determine the stream crossing frequency using GIS given a stream layer. However, since some sites are digitized as points and others as lines, it was not possible to accurately assign stream crossing frequencies.

Slope

We calculated slope from the USGS 30 meter NED using the Slope function in ArcGIS software (ESRI, 2005). The slope values for all cells intersecting the site were averaged to arrive at an average slope for each site. This estimate is very coarse and does not take into account the localized site-level characteristics.

There was not a significant association between log-transformed cost and slope (Regression, $P = 0.88$) or between cost per mile of road upgrading and slope (Regression, $P = 0.38$).

Soil Erodibility

We used KFFACT (the actual k factor used in the water erosion component of universal soil loss equation) from the USGS soils database as an estimate of soil erodibility. The weighted average KFFACT value for soils polygons intersecting the site was calculated to arrive at an average soil erodibility for each site. Each soil k factor was weighted by the proportion of the site it represents. This estimate is very coarse and does not take into account the localized site-level characteristics.

There was no association between cost or cost per mile and the weighted average soils k factor.

Labor

As a surrogate for labor costs, we collected information on unemployment rates and construction salaries from the California Employment Development Department and Rand California respectively. Data are at the county level and were assigned to sites based on the county associated with the site and the year the project began. When sites overlapped multiple counties, the data were assigned to sites based on a weighted average of how much of each site occurs within each county.

Counter to expectation, Box-Cox transformed cost was positively associated with log-transformed weighted average unemployment rate (Regression, coef = 56.127, $P = 0.0092$, $R^2 = 0.25$; Figure 109). Areas with higher average unemployment rates tended to have larger road upgrade projects (Regression, coef = 68.38, $P = 0.0018$, R^2adj = 0.38; Figure 110). There was not a significant effect of unemployment rate on log-transformed cost per mile of road upgrading (Regression, $P = 0.52$; Figure 111).

Unemployment rate data are measured at the county level, and it is possible that other county-level characteristics are driving the relationship between unemployment rates and number of miles upgraded. The fact that there is a correlation between unemployment rates and number of miles upgraded does not mean that there is a causal relationship. As can be seen in the graphs, one of the factors driving the relationship is the fact that the "outsloping" projects all cover a relatively large number of miles and occur in a relatively high unemployment rate area.

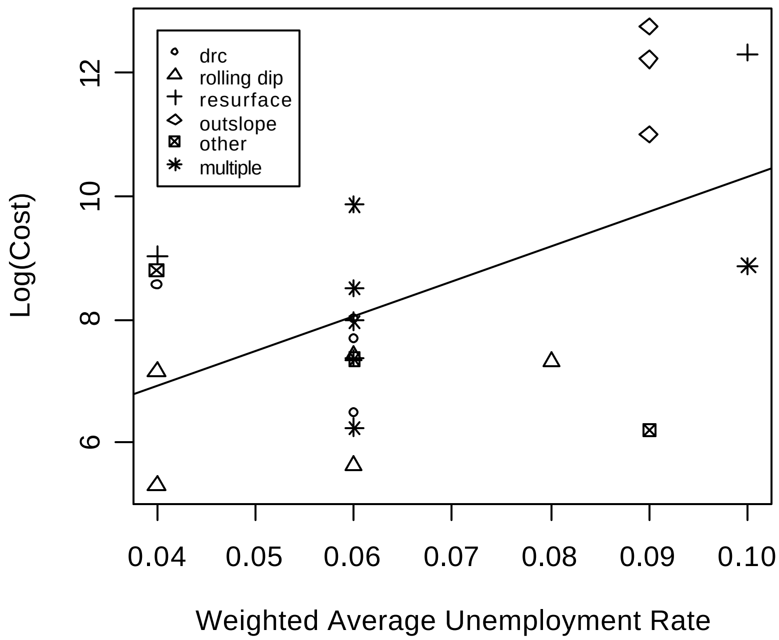

Figure 109. Log(cost) versus weighted average unemployment rate for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols.

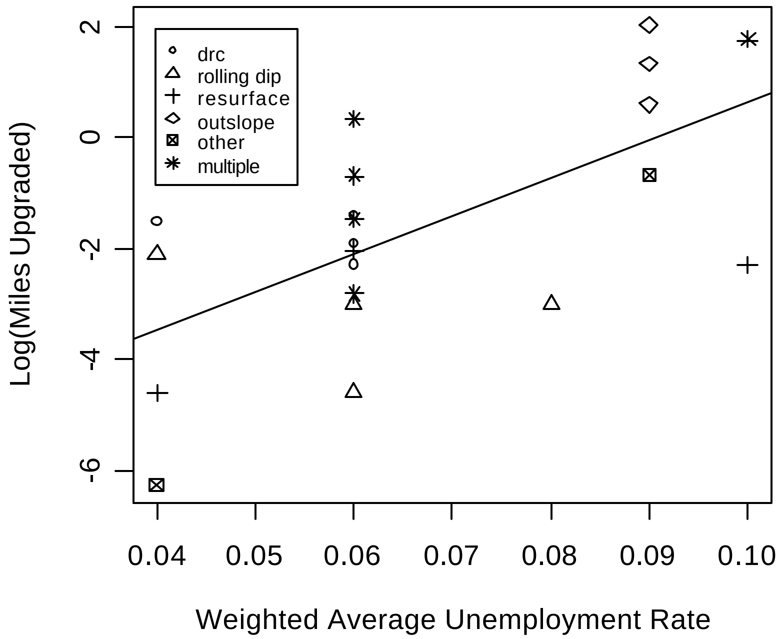

Figure 110. Log(miles upgraded) versus weighted average unemployment rate for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols.

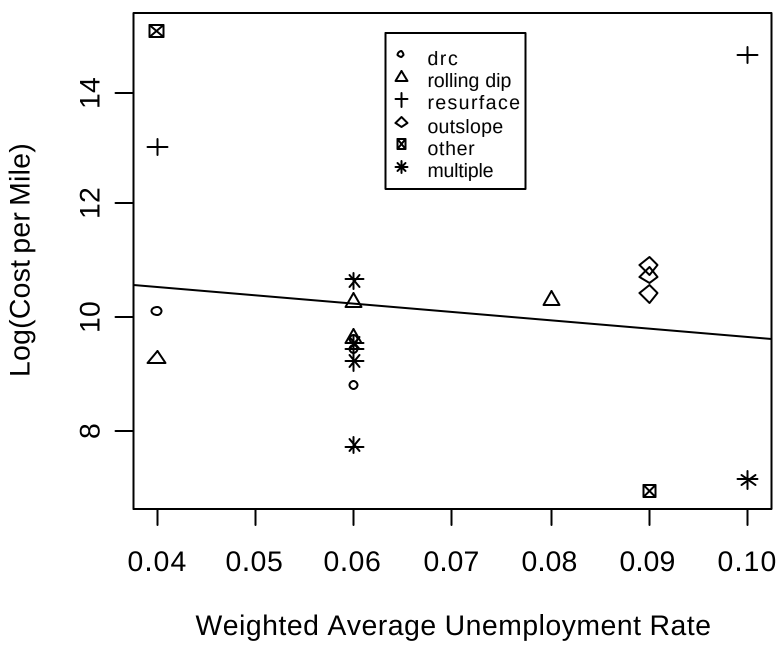

Figure 111. Log(cost per mile) versus weighted average unemployment rate for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols.

Grouping all upgrade types, log-transformed cost was significantly negatively associated with average annual construction wages ($1,000s) (Regression, coef = -0.13, P = 0.027, R^2adj =

0.29; Figure 112). Road upgrade projects in areas with higher average annual construction wages tended to be smaller than projects where wages were lower (Regression, coef = -0.22, P = 0.00020, R^2adj = 0.71; Figure 113). Road upgrade projects in areas with higher average annual construction wages tended to cost more per mile than projects where wages were lower (Regression, coef = 0.088, P = 0.038, R^2adj = 0.28; Figure 114).

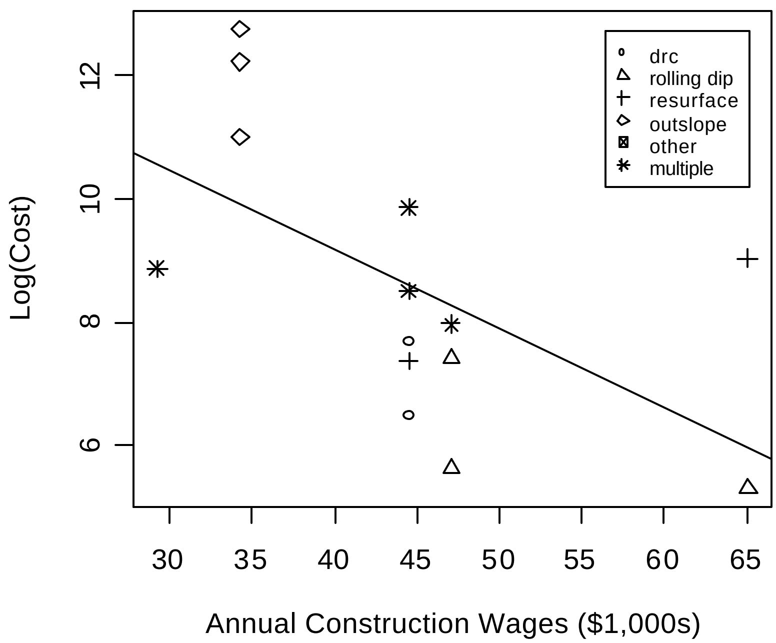

Figure 112. Log(cost) versus weighted average annual construction wages for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols.

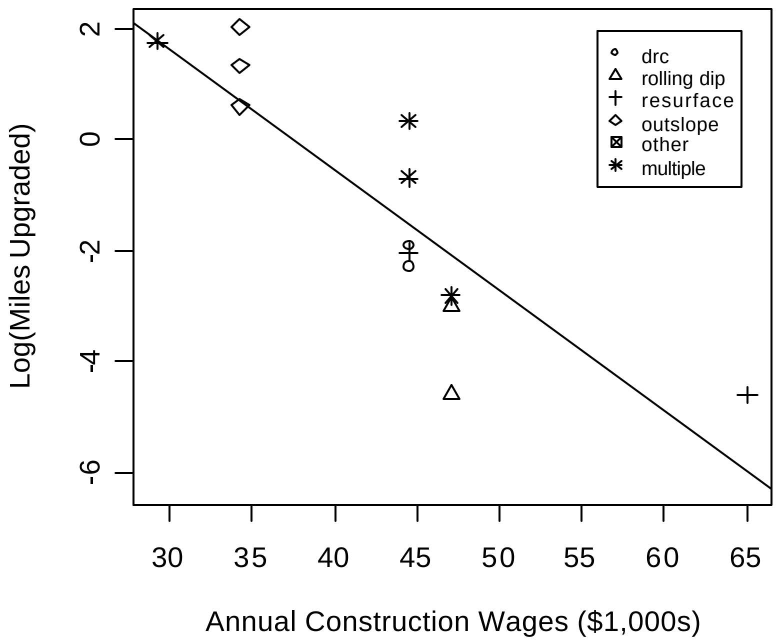

Figure 113. Log(miles upgraded) versus weighted average annual construction wages for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols.

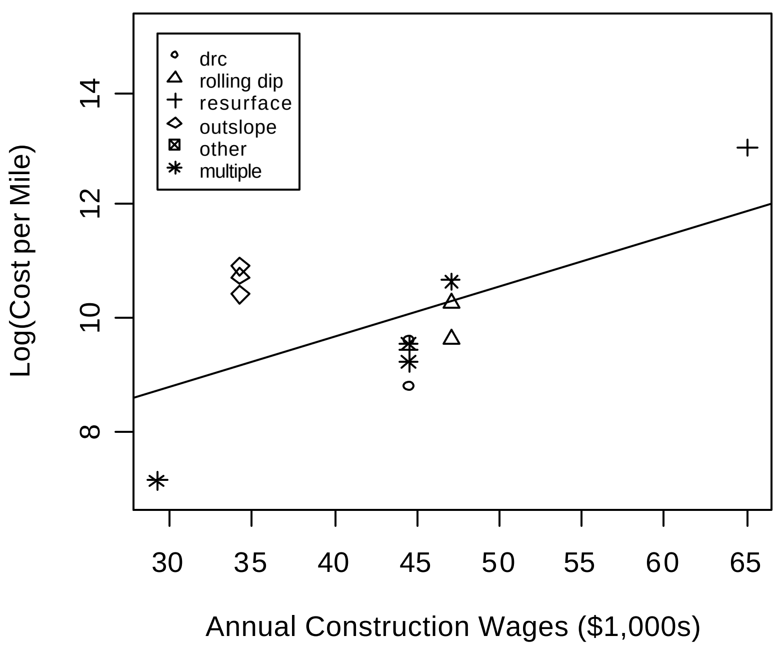

Figure 114. Log(cost per mile) versus weighted average annual construction wages for our sample of one road upgrade site per project. Upgrade types are distinguished by different symbols.

Grouping all road upgrade types, projects where contractors were required to pay prevailing wages cost significantly more than projects where prevailing wages were not required (Wilcoxon rank sum test, W = 89, P = 0.016; Figure 115). For each type of road upgrade that had sites where prevailing wages were and were not required, the sites with prevailing wages required cost more than those where prevailing wages were not required (Figure 116, Table 94). There was a marginally significant difference in log-transformed cost per mile between sites where prevailing wages were and were not required (Wilcoxon rank sum test, W = 66, P = 0.095; Figure 117). There was not a significant difference in the number of mile upgraded between sites where prevailing wages were and were not required (Wilcoxon rank sum test, W = 53, P = 0.54; Figure 118).

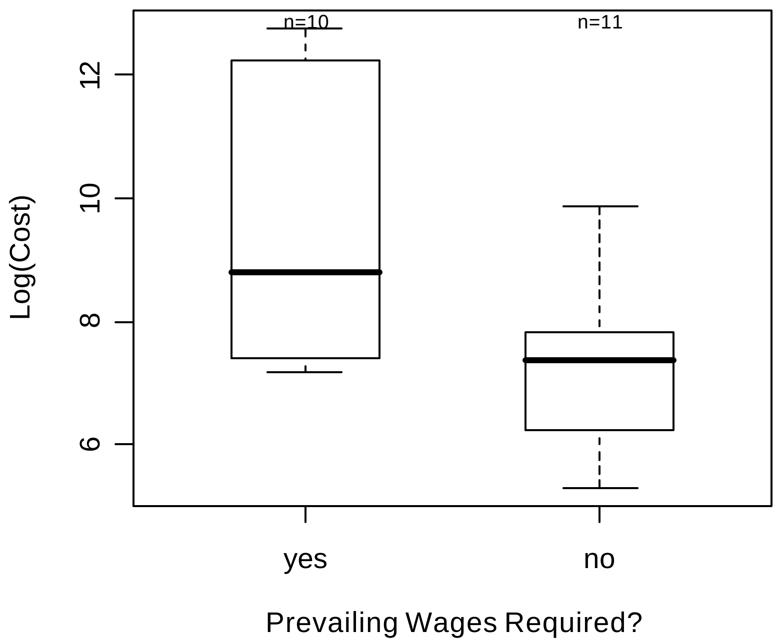

Figure 115. Boxplot of log(cost) for sites where prevailing wages were and were not required for our sample of one road upgrade site per project.

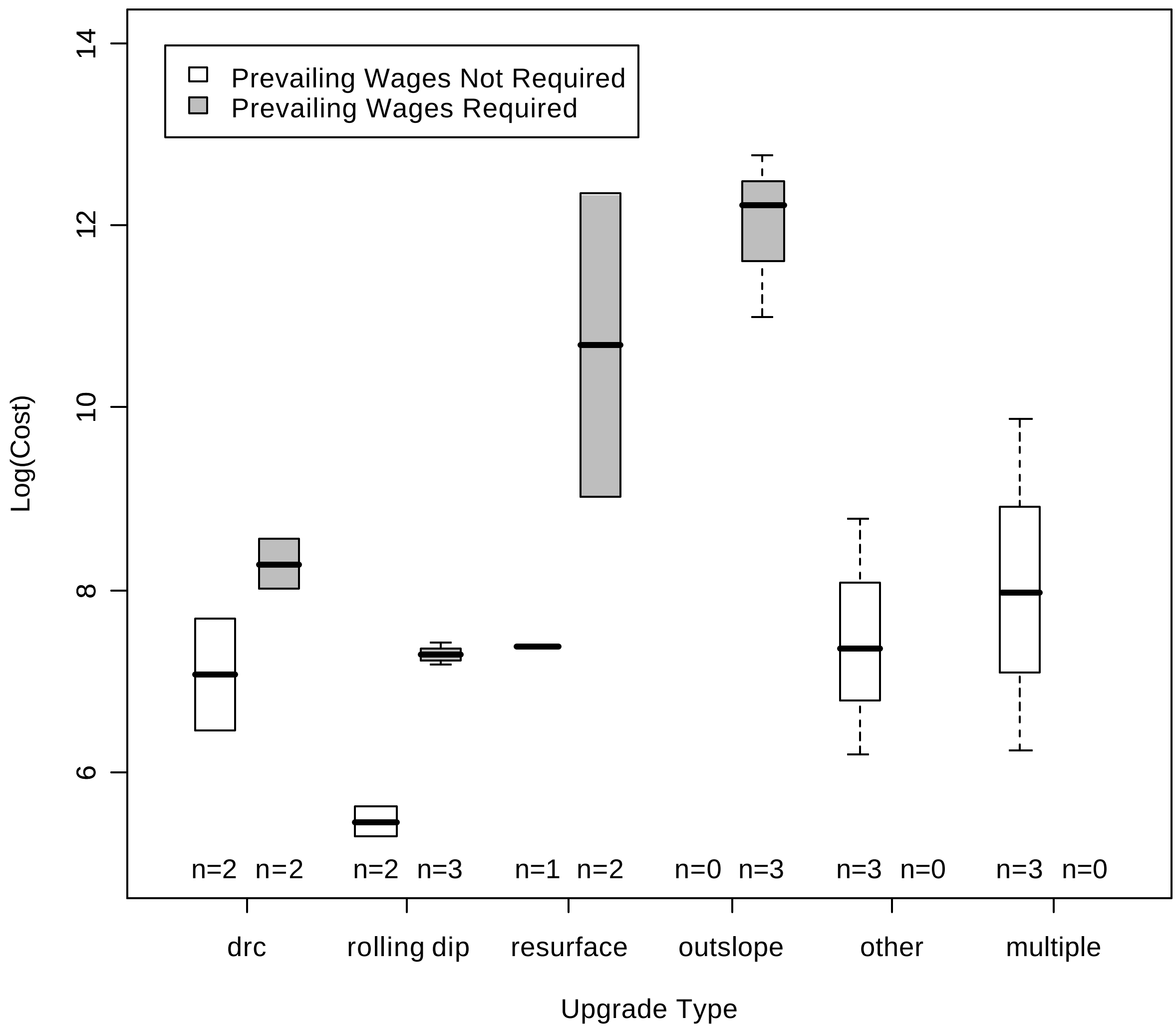

Figure 116. Boxplot of log(cost) for sites where prevailing wages were and were not required for each road upgrade type for our sample of one road upgrade site per project.

Table 94. Road upgrade cost by upgrade type and whether prevailing wages were required for our sample of one road upgrade site per project.

Upgrade Type	Prevailing Wages Required?	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost
drc	no	2	$650	$2,200	$1,425	1,096
drc	yes	2	$3,000	$5,235	$4,118	1,580
rolling dip	no	2	$200	$282	$241	58
rolling dip	yes	3	$1,300	$1,660	$1,487	180
resurface	no	1	$1,600	$1,600	$1,600	
resurface	yes	2	$8,400	$226,862	$117,631	154,476

Upgrade Type	Prevailing Wages Required?	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost
outslope	yes	3	$60,375	$347,889	$204,955	143,764
other	no	3	$500	$6,610	$2,898	3,260
multiple	no	3	$517	$19,246	$7,554	10,195

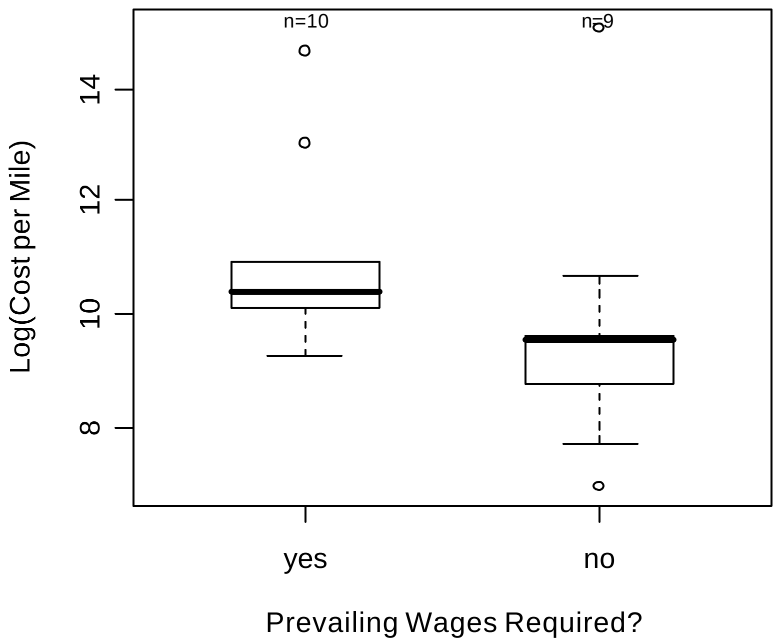

Figure 117. Boxplot of log(cost per mile) for sites where prevailing wages were and were not required for each road upgrade type for our sample of one road upgrade site per project.

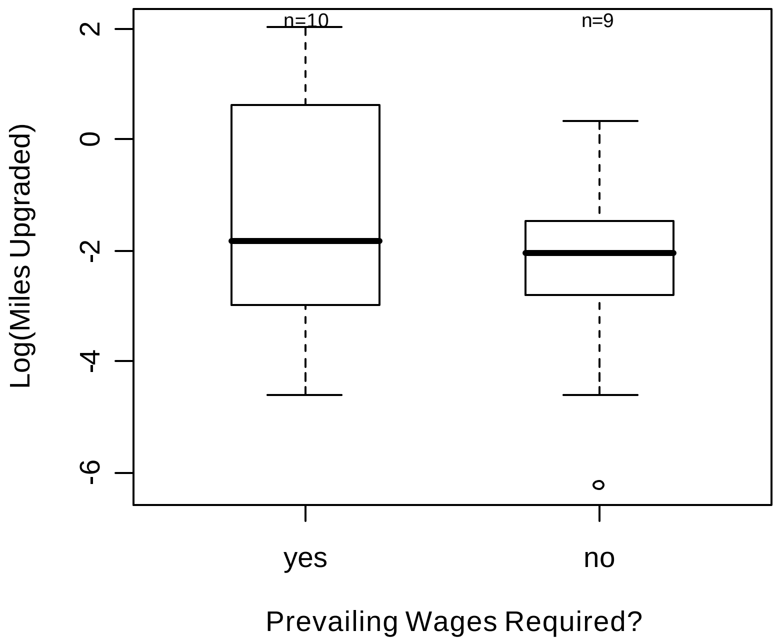

Figure 118. Boxplot of log(miles upgraded) for sites where prevailing wages were and were not required for each road upgrade type for our sample of one road upgrade site per project.

Land Ownership

According to Coffin (2000), road decommissioning projects on National Forest lands and particularly in areas managed under the Northwest Forest Plan are especially costly because of the large number of surveys and environmental documentation required relative to other areas. We anticipated that this factor might affect the cost of road upgrade projects as well. We used forest service administrative boundaries from the USDA Forest Service to determine which sites occur on National Forest land (Table 95).

There was a significant difference in log-transformed cost between sites that are on National Forest lands and those that are not (Wilcoxon rank sum test, W = 64, P = 0.035; Figure 119). Sites on National Forest lands cost more than other sites. There was a marginally significant difference in log-transformed cost per mile between sites that are on National Forest lands and those that are not (Wilcoxon rank sum test, W = 53, P = 0.099; Figure 120). There was a marginally significant trend for road upgrade projects to be larger on National Forest Service lands than elsewhere (Wilcoxon rank sum test, W = 52.5, P = 0.11; Figure 121).

Table 95. Road upgrade cost by whether the project occurred on National Forest or non-National Forest land.

National Forest?	Number of Sites	Minimum Cost	Maximum Cost	Average Cost	Standard Deviation of Cost	Median Cost
forest	4	$1,660	$347,889	$154,131	155,277	$133,488
not forest	19	$200	$226,862	$15,513	51,378	$ 2,200

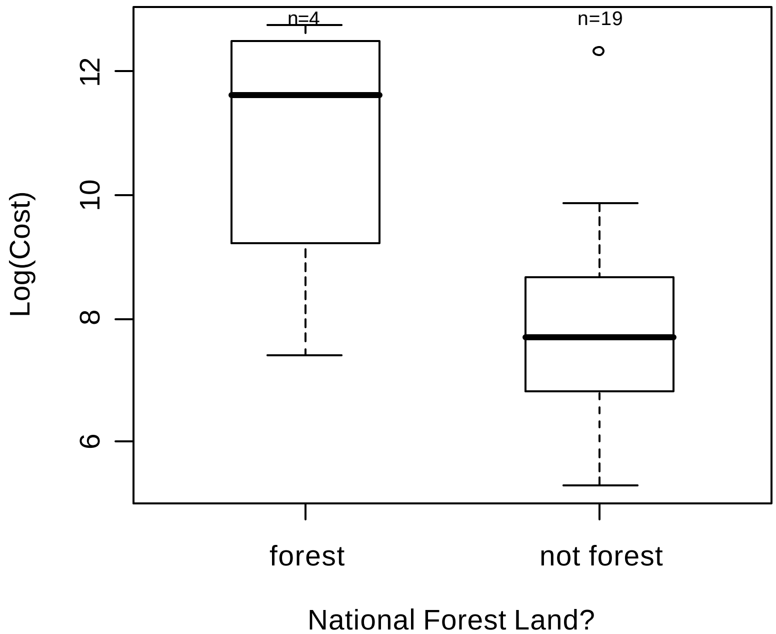

Figure 119. Boxplot of log(cost) for sites that are and are not on National Forest Service lands for our sample of one road decommissioning site per project.

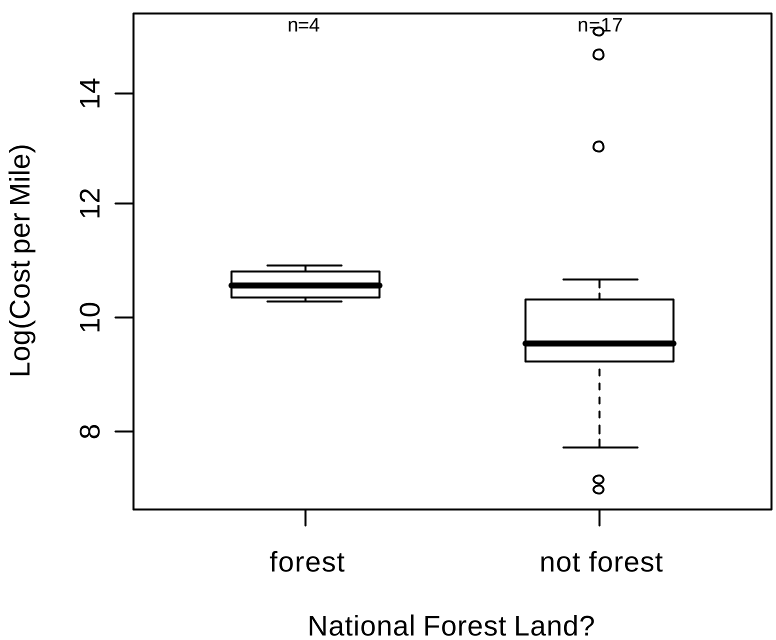

Figure 120. Boxplot of log(cost per mile) for sites that are and are not on National Forest Service lands for our sample of one road decommissioning site per project.

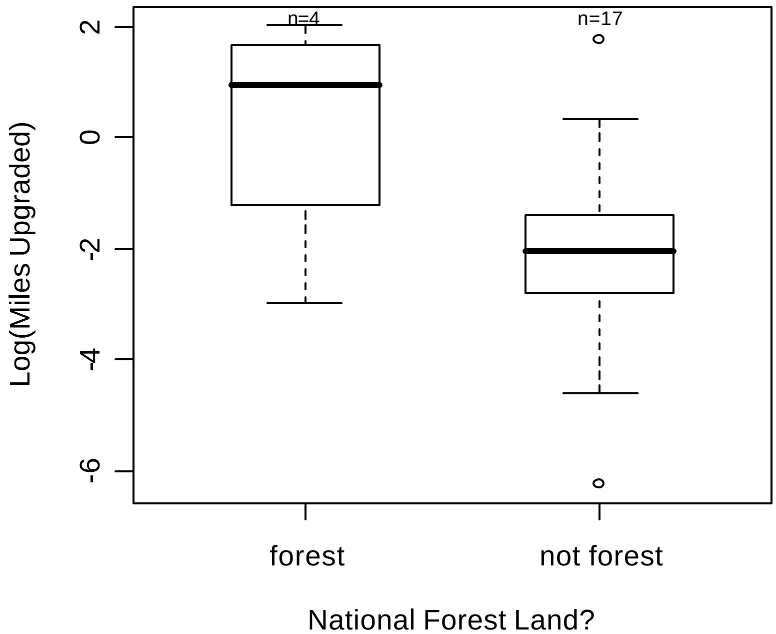

Figure 121. Boxplot of log(miles upgraded) for sites that are and are not on National Forest Service lands for our sample of one road decommissioning site per project.

Road Upgrading/Maintenance Analysis Summary

Type of upgrade and number of miles upgraded both significantly affected the cost of road upgrade projects. "Outsloping and rolling dip" projects tended to be the largest and most expensive. The cost of road upgrades increased significantly with number of miles upgraded, but cost per mile decreased with increasing project size, indicating possible economies of scale for larger projects. Cost per mile of road upgrading was marginally positively associated with distance to materials (excluding zero values).

Cost of road upgrade was positively associated with both distance to nearest urban area and average unemployment rate, both of which were positively associated with the number of miles upgraded and with each other. Projects cost significantly less where average annual construction wages were higher, probably because these projects tended to be smaller. Cost per mile of road upgrading was higher in areas with higher average annual construction wages. Road upgrade costs were significantly higher overall and marginally higher per mile for projects where prevailing wages were required and for projects on national forest lands than for other projects.

Land Acquisition

We limited our data collection to on-the-ground restoration activities, so we did not collect data on land acquisition projects. We can, however, summarize the cost of land acquisition for projects in the original CHRPD database from 3/14/05. Cost data in the CHRPD are recorded at the project level. To attempt to get accurate values of cost of land acquisition, we limited the projects to those with only one task (land acquisition), one measurement type, and one site per project. We also only looked at projects that began in 1998 or later. Land acquisition cost per acre is described in Table 96 and broken down by study area in Table 97.

Table 96. Summary of land acquisition cost data from the CHRPD (3/14/05). Sites are limited to projects since 1997 with only one task, one measurement type, and one site per project.

Number of Sites	Minimum Cost per Acre	Maximum Cost per Acre	Average Cost per Acre	Standard Deviation of Cost per Acre
269	$51.77	$1,313,502	$36,584	125,080

Table 97. Summary of land acquisition cost per acre by study area from data in the CHRPD (3/14/05). Sites are limited to projects since 1997 with only one task, one measurement type, and one site per project. Study areas pertain to geographic areas that are relevant to salmonid recovery planning in California (SONC=Southern Oregon/Northern California, NOSECA=Northern/Central California, SCACO=South Central California Coast).

Study Area	Number of Sites	Minimum Cost per Acre	Maximum Cost per Acre	Average Cost per Acre	Standard Deviation of Cost per Acre
None	87	$52	$128,087	$9,706	19,331
SONC	13	$2,541	$37,318	$10,249	10,293
NOCECA and SONC	10	$928	$53,727	$11,295	15,151
NOCECA	42	$138	$1,313,502	$98,626	229,981
Central Valley	52	$245	$32,590	$6,386	7,811
SCACO	65	$387	$871,845	$66,243	160,676

Summary and Recommendations

This report describes results of a pilot study involving use of salmon habitat restoration project data contained in the CHRPD to characterize restoration projects and model restoration costs. It documents our efforts to estimate such models by standardizing CHRPD project data and supplementing that data with information from restoration contractors and other external data sources. The cost models discussed here are broad in scope, covering a number of commonly used, on-the-ground restoration treatments. They are intended to be illustrative but not exhaustive of the types of analytical issues that can arise in restoration cost modeling.

Major challenges encountered in the course of data preparation included standardization of restoration project data and disaggregation of project costs among sites and tasks. These issues, which are discussed at length in a separate report (Hildner and Thomson, 2006), were addressed in our analysis as follows:

- On-the-ground restoration projects contained in the CHRPD are categorized into one or more of 105 treatment types. To make our analysis tractable, we mapped these 105 treatments into eight tasks: fencing, riparian planting, culvert replacement, existing culvert improvement, instream structures, bank stabilization, road decommissioning, and road surface upgrade/maintenance (excluding culverts).

- Our analysis required access to data on costs and restoration details at task- and site-specific levels. However, for restoration contracts involving work at multiple sites and/or multiple tasks at a single site, costs incurred by contractors are typically reported and monitored at the project level. Also, restoration outcomes are often described using multiple measurement units (e.g., miles/acres restored, trees planted, culverts removed/replaced, cubic yards of soil excavated) that are not available in standardized format for all projects; additionally, for projects involving multiple tasks/sites, it is not always clear which measurement units apply to which tasks or sites. Given these ambiguities in the CHRPD data, we were reluctant to arbitrarily allocate project-level costs and measurement units to individual tasks and sites, given the potentially high errors resulting from such allocation. Instead we asked contractors identified in the CHRPD as having conducted restoration in recent years in one or more of our eight restoration task categories to supplement their CHRPD data with task- and site-specific data.

Our analysis (see Table 98) yielded some significant results. However, the limited number of samples available for some restoration tasks hampered our ability to conduct multivariate analysis and to fully consider the potentially confounding effects of multiple, often highly correlated cost factors. For some of the restoration types we studied (e.g. riparian planting and culvert replacement), predictors examined explained much of the variability in restoration cost, but for other restoration types (e.g. instream structures, streambank stabilization), our simple, mostly univariate, analyses were unable to account for much of the variability in cost. Possible explanations for the lack of significant associations include:

- Data on the variables most important to cost were not collected.
- The data are not partitioned in ways that are meaningful to cost..
- Relationships between cost and predictor variables are complex (nonlinear) and/or are confounded by other variables not included in the analyses. Because our sample sizes were small, we were not able to conduct more complex, multivariate analyses.

Of the variables that we associated with restoration sites based on spatial location, the socioeconomic variables, such as average unemployment rate, were more likely to be significantly associated with cost than the environmental variables (slope and soil erodibility). Environmental variables, such as slope and soil erodibility need to accurately reflect the conditions at the site to have relevance to restoration cost, whereas socioeconomic variables need only reflect broader regional trends. For this reason, errors involved with spatial data and the coarse nature of the data for some of our environmental variables may obstruct their utility for restoration cost analysis. An exception is precipitation data, which is inherently less site-specific. Average annual precipitation was significantly associated with cost of riparian planting.

Data issues are the most notable constraint on future development of habitat restoration cost models, largely due to the need for standardized data on costs and restoration details at the task and site levels. To increase the availability of such data, we recommend: (1) that funding entities categorize their projects from the outset using a well-defined, comprehensive and standardized set of tasks, (2) that project costs be broken out by task and site, and (3) that a well-defined, comprehensive and standardized set of measurement units be used to quantify the details of each task at each site. Given the potential ambiguities that may be involved in implementing recommendation (2), explicit protocols may be needed to assign costs to tasks and to deal with fixed costs that may be applicable to multiple tasks. Standardized project data are probably most efficiently obtained by incorporation into the routine information requirements of restoration proposals and contract reports. Trade-offs will likely need to be made in terms of establishing information requirements that are adequate to their purpose but not unduly burdensome on contractors. In Appendix 2 we present a possible data collection structure. The structure and variable definitions should be taken as a starting point; ideally, restoration contractors, other restoration specialists, and database designers would be consulted in the preparation of a final, validated data collection design.

Standardization can serve purposes other than cost models and recovery planning. While funding entities can effectively monitor individual restoration projects without standardization, standardization can facilitate their ability to track cumulative accomplishments across all projects and relate costs to accomplishments. Standardization can also facilitate their ability to compare and evaluate different aspects of their program and to be strategic and cost-effective in how monies are spent. Such accountability is important, given the substantial public monies being spent on restoration.

Finally, it is important to note that the measurement units used to report project outcomes typically reflect engineering accomplishments (i.e., number of items installed, repaired, replaced or removed) and that our cost models reflect available data in this regard. Substantial improvements over such models could be made if restoration costs could be linked directly to salmon population changes or to reductions in limiting factors affecting salmon survival and recovery. Given the spatial linkages between upstream/downstream and upslope/downslope habitat conditions, it is not always possible to evaluate the effect of any single restoration project on limiting factors without considering the larger spatial context within which it occurs. Further research that focuses more on networks of spatially linked projects and associated costs may be useful in this regard.

Table 98. Summary of results from restoration cost analyses. Rows represent response variables and columns represent predictors. S = significant association (P <= 0.05); MS = marginally significant association (0.05 < P <= 0.10); NS = no significant association (P > 0.10).

Response	Size (Length, Area, # of Structures)	Culvert Diameter	Culvert Length	Rock Size	Wood Diameter	Number of Sites per Project	Average Distance between Sites	Number of Stream Crossings (-0)	Excavation	Material Type or Work Type	Type of Road Above Culvert	Site Accessibility	Site Prep. Difficulty	Distance to Materials	Materials Onsite?	Average Slope	Soil Erodibility	Precipitation	Prevailing Wages Required	Average Construction Wages	Average Unemployment	Population Density	Distance to Nearest Urban Area	Stream Order	Stream Flow (cfs)	National Forest Land?	Experience Level of Contractor	Electrification	Irrigation	Construction (onsite/precast)
Fencing: Cost per Foot	NS									NS		**				NS			NS	NS	NS							**S**		
Riparian Planting: Cost per Acre	**S-**									NS		MS	NS			NS		**S-**	**S**	MS+	**S-**								NS	
Cost per Acre Controlling for Acres Planted										NS		NS	**S**			NS		**S-**	**S**	NS	**S-**								MS	
Culvert Replacement: Cost per Culvert		**S+**	**S+**						**S+**	**S**	**S**													**S**	**S+**					NS
Instream Structures: Cost per Structure	NS			MS+	NS					NS		NS		NS	NS				NS	NS	**S-**	MS+	NS	NS	NS					
Cost per Structure, Rock Sites Only														**S+**																
Bank Stabilization: Cost per Foot	NS								NS	NS									MS		NS			NS	MS+					
Road Decommissioning: Cost	**S+**					**S-**	NS	**S+**	MS+	NS				NS		NS	NS						NS			MS				
Cost Controlling for Miles Decommissioned						NS	NS									NS				**S+**	**S-**									
Road Decommissioning: Cost per Mile	NS					NS	NS	NS	NS	NS				NS		NS	NS			NS	MS-		NS			NS				
Miles Decommissioned						**S-**		**S+**															**S+**			**S**				
Road Decommissioning: Cost per Crossing									MS+																					
Road Upgrading: Cost	**S+**									**S**		NS		NS		NS	NS		**S**	**S-**	**S+**		**S+**			**S**	NS			
Road Upgrading: Cost per Mile	**S-**									NS		NS		MS+*		NS	NS		MS	**S+**	NS		NS			MS	NS			
Miles Upgraded										**S**		NS							NS	**S-**	**S+**		**S+**			MS				

**All fencing projects were on easily accessible sites

*Zero values for distance to materials were removed from the analysis

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Appendix 1. Example Mailing Materials

Cover Letter From First Mailing:

NOAA Fisheries
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060

March 4, 2005

Name
Address

Dear __________,

NOAA Fisheries is in the process of developing cost models to predict the costs of salmonid habitat restoration projects. We are writing you to request that you help by providing data on one or more of your recent restoration projects.

We have access to data on many past and present restoration projects through the California Habitat Restoration Project Database (CHRPD). To create cost models, however, we need project costs broken out by location and by task. To this end, we are requesting information from you on one or more of your projects.

In an effort to minimize the amount of time it will take you to provide this information, we have created a map and a set of forms for each project. The map indicates the site(s) where the restoration work was completed, and the forms provide basic project information including total cost. We ask that you verify or correct the spatial information and provide the dollar amount spent on each relevant restoration task (listed on the forms) at each site. In addition, there is a series of auxiliary questions for each task. Instructions are included for your convenience.

This information is being collected for modeling purposes only and will be made public only in aggregate form. Our intent is not to regulate or restrict the restoration projects that we are asking you about, but rather to help us get a better understanding of the factors affecting restoration costs.

Note: Please do not be concerned by the number of forms. The forms include questions for all of the types of restoration tasks we are interested in. Most likely, many of these tasks will not apply to your project and can be left blank.

Please return completed form(s) to: **Kimberly Baker**
Pacific States Marine Fisheries Commission
830 S Street
Sacramento, CA 95814

If you have questions, please call Kimberly Baker at (916) 445-0970, or email kbaker@dfg.ca.gov.

We hope that you will find the forms easy to fill out and will help us by providing the requested information by **April 10**. If you are not the correct person to provide this information, please pass this packet along to the correct individual. We greatly appreciate your assistance, as this data will be invaluable to our project. We will contact you by phone in the near future to see if you have any questions. Thank you for your time.

Sincerely,

Cindy Thomson
Economics Team Leader
NOAA Fisheries
Santa Cruz Laboratory

Cover Letter From Second Mailing – Contacts With Less Than 6 Sites:

NOAA Fisheries
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060

March 10, 2005

Name
Address

Dear _________,

NOAA Fisheries is in the process of developing cost models to predict the costs of salmonid habitat restoration projects. We are writing you to request that you help by providing data on one of your recent restoration projects.

We have access to data on many past and present restoration projects through the California Habitat Restoration Project Database (CHRPD). To create cost models, however, we need project costs broken out by location and by task. To this end, we are requesting information from you on one of your projects.

In an effort to minimize the amount of time it will take you to provide this information, we have created a map and a set of forms for the project. The map indicates the sites where the restoration work was (or will be) completed, and the forms provide basic project information including total cost. We ask that you verify or correct the spatial information and provide the dollar amount spent on each relevant restoration task (listed on the forms) at each site. In addition, there is a series of auxiliary questions for each task. Where work has not yet been completed, please provide proposed or estimated values. Instructions are included for your convenience.

This information is being collected for modeling purposes only and will be made public only in aggregate form. Our intent is not to regulate or restrict the restoration projects that we are asking you about, but rather to help us get a better understanding of the factors affecting restoration costs.

Note: Please do not be concerned by the number of forms. The forms include questions for all of the types of restoration tasks we are interested in. Most likely, many of these tasks will not apply to your project and can be left blank.

Please return completed form(s) to: **Kimberly Baker**
Pacific States Marine Fisheries Commission
830 S Street
Sacramento, CA 95814

If you have questions, please call Kimberly Baker at (916) 445-0970, or email kbaker@dfg.ca.gov.

We hope that you will find the forms easy to fill out and will help us by providing the requested information by **April 20**. If you are not the correct person to provide this information, please pass this packet along to the correct individual. We greatly appreciate your assistance, as this data will be invaluable to our project. We will contact you by phone in the near future to see if you have any questions. Thank you for your time.

Sincerely,

Cindy Thomson
Economics Team Leader
NOAA Fisheries
Santa Cruz Laboratory

Cover Letter From Second Mailing – Contacts With 6 Or More Sites:

NOAA Fisheries
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060

March 10, 2005

Name
Address

Dear ___________,

NOAA Fisheries is in the process of developing cost models to predict the costs of salmonid habitat restoration projects. We are writing you to request that you help by providing data on some of your recent restoration projects.

We have access to data on many past and present restoration projects through the California Habitat Restoration Project Database (CHRPD). To create cost models, however, we need project costs broken out by location and by task. To this end, we are requesting information from you on some of your projects.

In an effort to minimize the amount of time it will take you to provide this information, we have created a map and a set of forms for each project. The map indicates the sites where the restoration work was (or will be) completed, and the forms provide basic project information including total cost. We ask that you verify or correct the spatial information and provide the dollar amount spent on each relevant restoration task (listed on the forms) at each site. In addition, there is a series of auxiliary questions for each task. Where work has not yet been completed, please provide proposed or estimated values. Instructions are included for your convenience.

This information is being collected for modeling purposes only and will be made public only in aggregate form. Our intent is not to regulate or restrict the restoration projects that we are asking you about, but rather to help us get a better understanding of the factors affecting restoration costs.

Note: Please do not be concerned by the number of forms. The forms include questions for all of the types of restoration tasks we are interested in. Most likely, many of these tasks will not apply to your projects and can be left blank.

If possible, we would like you to provide information for all project sites included in this mailing. However, if that is too much of a burden for you, please provide data for the 5 sites that you feel are most representative of your work.

Please return completed form(s) to:

Kimberly Baker
Pacific States Marine Fisheries Commission
830 S Street
Sacramento, CA 95814

If you have questions, please call Kimberly Baker at (916) 445-0970, or email kbaker@dfg.ca.gov.

We hope that you will find the forms easy to fill out and will help us by providing the requested information by **April 20**. If you are not the correct person to provide this information, please pass this packet along to the correct individual. We greatly appreciate your assistance, as this data will be invaluable to our project. We will contact you by phone in the near future to see if you have any questions. Thank you for your time.

Sincerely,

Cindy Thomson
Economics Team Leader
NOAA Fisheries
Santa Cruz Laboratory

Cover Letter From Third Mailing:

NOAA Fisheries
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060

March 17, 2005

Name
Address

Dear ____________,

NOAA Fisheries is in the process of developing cost models to predict the costs of salmonid habitat restoration projects. We are writing you to request that you help by providing data on one of your recent restoration projects.

We have access to data on many past and present restoration projects through the California Habitat Restoration Project Database (CHRPD). To create cost models, however, we need project costs broken out by location and by task. To this end, we are requesting information from you on one of your projects.

In an effort to minimize the amount of time it will take you to provide this information, we have created a map and a set of forms for the project. The map indicates the sites where the restoration work was (or will be) completed, and the forms provide basic project information including total cost.

Your project has many sites, and we do not want to unduly burden you with paperwork, so we ask that you choose 5 sites that are representative of this project and fill out the forms for the selected sites. If you are able to provide data for additional sites, we can provide more forms, or we can accept the data in other formats if necessary – please let us know.

Please verify or correct the spatial information (maps) and provide the dollar amount spent on each relevant restoration task (listed on the forms) at each of the selected sites. In addition, there is a series of auxiliary questions for each task. Where work has not yet been completed, please provide proposed or estimated values. Instructions are included for your convenience.

This information is being collected for modeling purposes only and will be made public only in aggregate form. Our intent is not to regulate or restrict the restoration projects that we are asking you about, but rather to help us get a better understanding of the factors affecting restoration costs.

Note: Please do not be concerned by the number of forms. The forms include questions for all of the types of restoration tasks we are interested in. Most likely, many of these tasks will not apply to your project and can be left blank.

Please return completed form(s) to: **Kimberly Baker**
Pacific States Marine Fisheries Commission
830 S Street
Sacramento, CA 95814

If you have questions, please call Kimberly Baker at (916) 445-0970, or email kbaker@dfg.ca.gov.

We hope that you will find the forms easy to fill out and will help us by providing the requested information by **April 25**. If you are not the correct person to provide this information, please pass this packet along to the correct individual. We greatly appreciate your assistance, as this data will be invaluable to our project. We will contact you by phone in the near future to see if you have any questions. Thank you for your time.

Sincerely,

Cindy Thomson
Economics Team Leader
NOAA Fisheries
Santa Cruz Laboratory

Instruction Sheet – First and Second Mailing:

Instructions

NOAA Fisheries is in the process of developing cost models to predict the costs of salmonid habitat restoration projects, and your help in filling out the data on the forms in this packet will be invaluable. Data collected will supplement data already in the California Habitat Restoration Project Database (CHRPD). The CHRPD is a statewide database of stream habitat restoration projects that benefit anadromous fish and is being developed through the cooperative efforts of the Pacific States Marine Fisheries Commission, the California Department of Fish and Game, and NOAA Fisheries.

This information is being collected for modeling purposes only. The information that you provide will not be used for regulatory purposes, and data from this project will only be made public in aggregate form.

Instructions

1. On the enclosed Project Form we have included some basic project information from the CHRPD and some project level questions. Please check the information for accuracy and make corrections if you find any errors. Please fill in the empty boxes.
2. We have provided a map of your project site(s). Please check the map for accuracy. If we have missed or misplaced any of your project locations, please draw and label the correct site on the map. Cross out any incorrect locations. Attach additional maps if necessary.
3. For each site that needed correction, check the box next to "Location Corrected?" on the appropriate site's form. If you have added locations, please provide the information about each added site on the blank site forms provided.

For each site, we have provided a set of questions (forms to be filled in) for each task that we are interested in. It is likely that all of these tasks do not apply to each site. Please fill in the requested information for all tasks that were (or will be) performed at each site. If the project has not yet been completed, please provide proposed or estimated values.

If all of the costs at a site are not accounted for in these tasks, please provide a brief description or list of unaccounted-for costs in the box labeled 'Additional information about this site?' at the top of the appropriate site's form. Attach additional sheets if necessary.

Please return completed forms to: Kimberly Baker
Pacific States Marine Fisheries Commission
830 S Street
Sacramento, CA 95814

If you have questions, please call Kimberly Baker at (916) 445-0970, or email kbaker@dfg.ca.gov.

Again, thank you for your help. We appreciate your cooperation and timely response.

Instruction Sheet – Third Mailing:

Instructions

NOAA Fisheries is in the process of developing cost models to predict the costs of salmonid habitat restoration projects, and your help in filling out the data on the forms in this packet will be invaluable. Data collected will supplement data already in the California Habitat Restoration Project Database (CHRPD). The CHRPD is a statewide database of stream habitat restoration projects that benefit anadromous fish and is being developed through the cooperative efforts of the Pacific States Marine Fisheries Commission, the California Department of Fish and Game, and NOAA Fisheries.

This information is being collected for modeling purposes only. The information that you provide will not be used for regulatory purposes, and data from this project will only be made public in aggregate form.

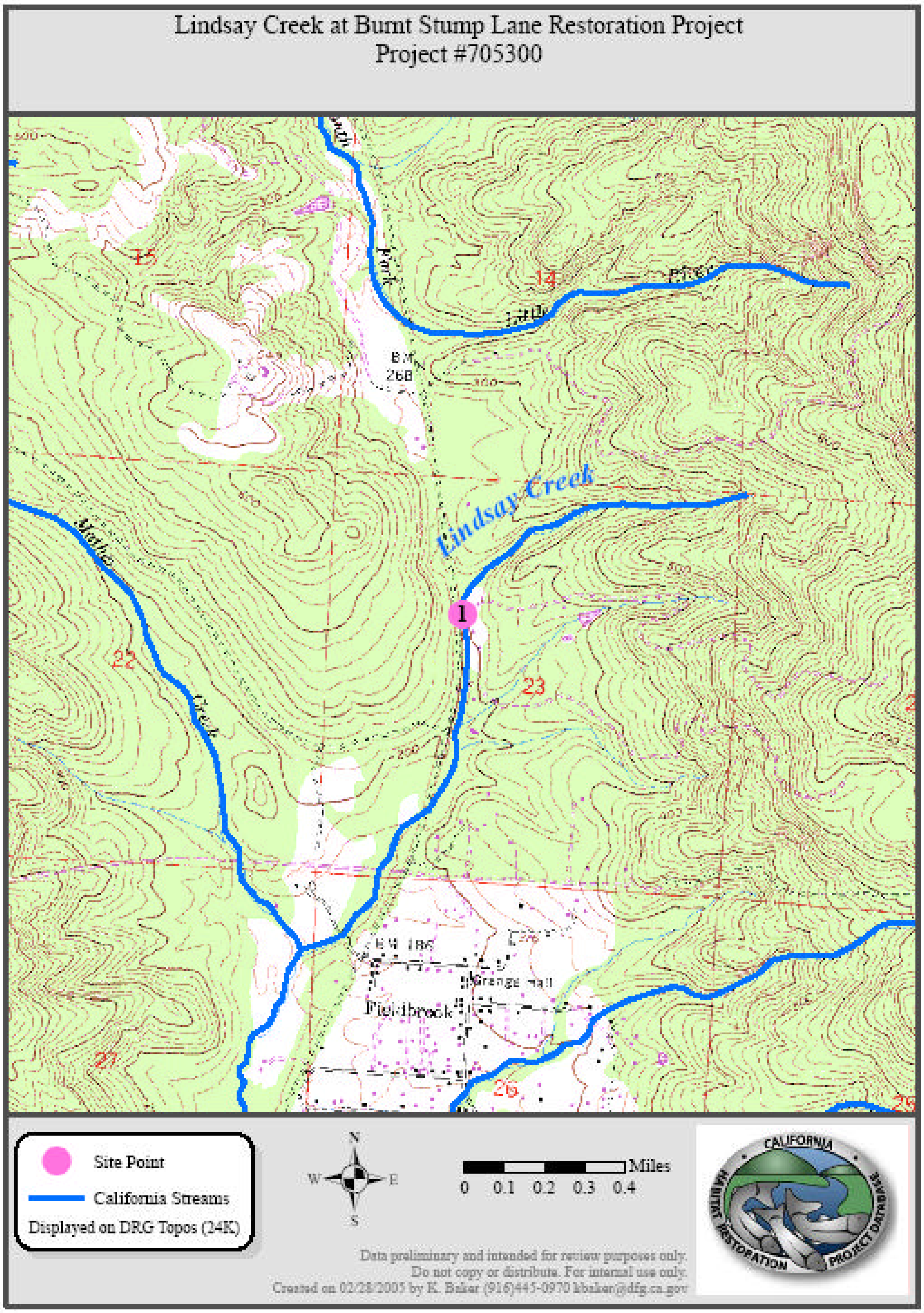
Instructions

1. On the enclosed Project Form(s) we have included some basic project information from the CHRPD and some project level questions. Please check the information for accuracy and make corrections if you find any errors. Please fill in the empty boxes.
2. Choose 5 sites that are representative of the project(s) and enter the project ID and site number for each at the top of one of the site forms, then complete the steps below.
3. We have provided a map of your project sites. Please check the map for accuracy. If we have missed or misplaced any of your project locations, please draw and label the correct site on the map. Cross out any incorrect locations. Attach additional maps if necessary.
4. For each site that needed correction, check the box next to "Location Corrected?" on the appropriate site's form.
5. For each site, we have provided a set of questions (the site forms) for each task that we are interested in. It is likely that all of these tasks do not apply to each site. Please fill in the requested information for all tasks that were (or will be) performed at each site. If the project has not yet been completed, please provide proposed or estimated values.
6. If all of the costs at a site are not accounted for in these tasks, please provide a brief description or list of unaccounted-for costs in the box labeled 'Additional information about this site?' at the top of the appropriate site's form. Attach additional sheets if necessary.
7. Please return completed forms to: Kimberly Baker
Pacific States Marine Fisheries Commission
830 S Street
Sacramento, CA 95814

If you have questions, please call Kimberly Baker at (916) 445-0970, or email kbaker@dfg.ca.gov.

Again, thank you for your help. We appreciate your cooperation and timely response.

Example Map From First Mailing:



Example Project Form From First Mailing:

Project Form

Lindsay Creek at Burnt Stump Lane Restoration Project

Gray fields: please write in any corrections or additions. *White fields: please write in requested information.*

Project ID	**705300**	
Begin Year	2004	*The year work on the project began.*
Total Cost	$32,504.00	*(Includes labor, equipment, materials and in-kind contributions associated with this project.)*
Purpose	Remove shotgun culvert and replace with a manufactured bridge on Lindsay Creek at Burnt Stump Lane.	
Contact Name	Tim Broadman	
Title		
Agency	Tim Broadman	
Address	175 Burnt Stump Lane, Fieldbrook, CA 95519	
Phone	707-839-2197	
Fax	707-826-9561	
Email	fukuevan@northcoast.com	
Experience		*Approximately how many similar projects has the contractor worked on?*
Permitting Cost:		*If known, please provide the (approximate) permitting cost for this project.*
Planning and Design Cost:		*If known, please provide the (approximate) cost of planning and design for this project.*

Example Site Form From First Mailing:

Lindsay Creek at Burnt Stump Lane Restoration Project

Site 1

(CHRPD code 7200456)

Site Name	Lindsay Creek (Burnt Stump Ln) - fish passage improvement
Location Corrected?	☐ *(Please make changes on attached quad map or attach additional maps.)*
Additional information about this site?	

Fill in blocks only for those tasks occurring at this site. Cost reported for each task should include labor, equipment, materials and in-kind contributions associated with this project site.

Road Upgrade/Maintenance (Excluding Culverts)

Road Upgrade Cost:	Miles Upgraded:	Upgrade Type (circle one):
		outsloping/insloping/crowning ditch relief culverts rolling dips waterbars resurfacing other

Road Decommissioning

Road Decom. Cost:	Miles Decommissioned:	Decommission Type (circle one):[a]	# of Stream Crossings Treated:
		complete obliteration partial closure only	

[a] *Complete = full topographic obliteration. Partial = hydrologic obliteration. Closure only = close road to avoid need for regular maintenance; storm-proofing.*

Bank Stabilization (Excluding Riparian Planting)

Bank Stabilization Cost:	Streambank Treated (lineal feet):

Primary Stabilization Material (circle one):[a]	Material Complexity (circle one):[b]	Excavation (circle one):[c]	Stream Order (circle one):
wood rock/boulders both bioengineered other	minimal moderate substantial	minimal moderate extensive	1st order 2nd order 3rd order and above

[a] *Wood = logs/rootwads/tree bundles. Rock/Boulders = boulder/rock/cobble structures. Both = both wood and rock/boulder. Bioengineered = planting/placement of live plants/cuttings. Other = concrete/wire/geotextile fabric, etc.*

[b] *Minimal = native channel gravel/rock, available onsite. Moderate = riprap, onsite plants. Substantial = large logs (>24" diameter), large rootwads, large toe rock, offsite plants.*

[c] *Minimal = hand tools. Moderate = small equipment, moderate excavation. Extensive = heavy equipment, slope reconstruction.*

Site 1 - Page 1

Lindsay Creek at Burnt Stump Lane Restoration Project

Site 1

(CHRPD code 7200456)

Instream Structure Installation

Instream Structures Cost:	Number of Structures:	Stream Length Treated (miles):	Site Accessibility (circle one): [a]	Stream Order (circle one):
			easy average difficult	1st order 2nd order 3rd order and above

Primary Structure Material (circle one)[b]	Materials Onsite?	Distance to Materials (miles):	Rock Size (tons per boulder):	Wood Diameter (inches):
wood rock/boulders both bioengineered other	☐			

[a]. *Easy = easy access. Average = partial vehicle access. Difficult = very limited/no vehicle access.*

[b]. *Wood = logs/rootwads/tree bundles. Rock/Boulders = boulder/rock/cobble structures. Both = both wood and rock/boulder. Bioengineered = planting/placement of live plants/cuttings. Other = concrete/wire/geotextile fabric, etc.*

Culvert Replacement (Excluding Road Decommissioning Projects)

Culvert Replacement Cost:	Diameter of New Culvert (inches):	Culvert or Bridge Length (feet):	Construction (circle one):
			onsite precast

Fill Volume Excavated (cubic yards):	Number of Culverts:	Type of Road Above Culvert (circle one):	Culvert Type (circle one):
		forest road minor 2 lane major 2 lane highway/4+ lanes	corrugated steel pipe SSP open bottom arch open-bottom concrete box/arch closed concrete box concrete circular or arch pipe log/wood bridge

Culvert Improvement (Excluding Road Decommissioning)

Culvert Improvement Cost:	Type of Culvert Improvement (circle one):	Weir Installed? (circle one):	Culvert Length (feet):
	Washington baffles, metal Washington baffles, wood CMP steel ramp baffles Other	Log weir Boulder weir None	

Site 1 - Page 2

Lindsay Creek at Burnt Stump Lane Restoration Project

Site 1

(CHRPD code 7200456)

Riparian Planting (Excluding Road Decommissioning Projects)

Riparian Planting Cost:	Area Planted (acres):	Trees Planted:	Plant Material Cost:[a]	Site Accessibility (circle one):[b]
			minimal moderate substantial	easy average difficult

Site Preparation Difficulty:[c]	Irrigation (circle one):	Protection (circle one):
easy average difficult very difficult	drip irrigation hand irrigation none	chemical tubing shade protection none

[a] *Minimal = bare root, native materials readily available, materials donated - in-kind cost not reported. Moderate = bare root, weed block, landscape fabric, mulch. Substantial = 1-5+ gal plants, weed block, landscape fabric/mulch, most materials purchased, native material not readily available or grown from seed*

[b] *Easy=easy vehicle access. Average=partial vehicle access. Difficult=very limited/no vehicle access*

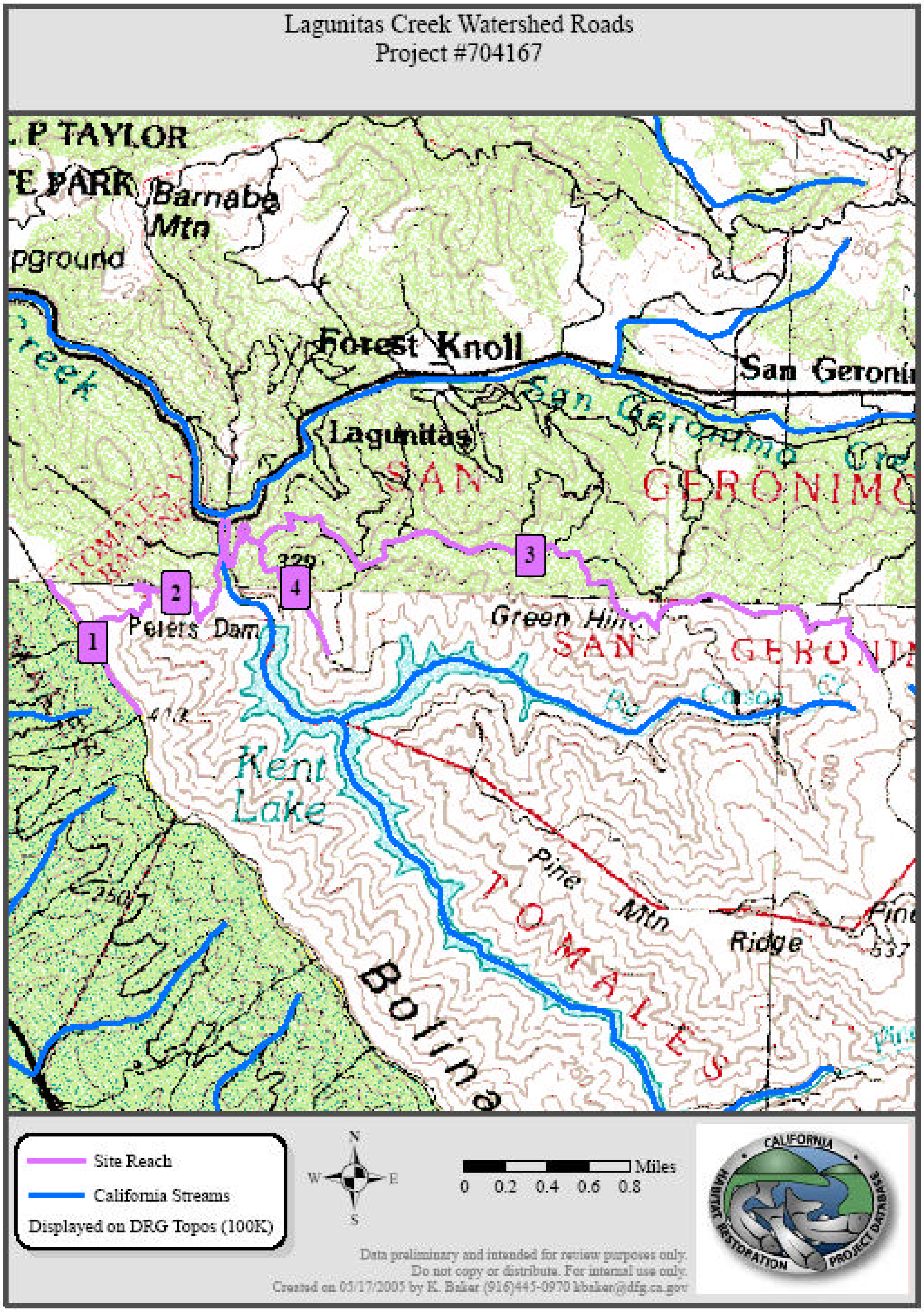
[c] *Easy = small debris/duff removal, slight sloping. Average = pasture sod removal. Difficult = non-native removal, machine labor. Very Difficult = non-native removal, hand labor*

Fencing

Fencing Cost:	Fence Length Installed (lineal feet):	Fence Material Complexity (circle one):[a]	Fence Electrified?
		simple average complex	☐

[a] *Simple = barb/hog wire, no gates, few posts. Average = livestock fence, metal, wood/metal corners, few gates, moderate # posts. Complex = smooth wire, New Zealand/similar type, deer exclusion.*

Example Map From Second Mailing:



Example Project Form From Second Mailing:

Project Form

Lagunitas Creek Watershed Roads

Gray fields: please write in any corrections or additions. *White fields: please write in requested information.*

Project ID	**704167**	
Begin Year	2001	*The year work on the project began.*
Total Cost	$89,994.00	*(Includes labor, equipment, materials and in-kind contributions associated with this project.)*
Purpose	Improve 7 miles of actively used dirt roads and close 1 mile of an abandoned dirt road to reduce sediment sources and improve streambed conditions for the benefit of Coho and steelhead.	
Contact Name	Thomasin Curtis	
Title	Grant Specialist	
Agency	Marin Municipal Water District	
Address	220 Nellen Avenue, Corte Madera, CA 94925-1169	
Phone	415-945-1542	
Fax	415-924-2630	
Email	tcurtis@marinwater.org	
Experience	0	*Approximately how many similar projects has the contractor worked on?*
Permitting Cost:	$0.00	*If known, please provide the (approximate) permitting cost for this project.*
Planning and Design Cost:	$0.00	*If known, please provide the (approximate) cost of planning and design for this project.*
Status (circle one)	Proposed In progress Completed	If the project is in progress, please indicate the percent completed:
Prevailing Wages Required?	☐	*Check this box if you are required to pay prevailing wages on this project.*

Example Site Form From Second Mailing:

Lagunitas Creek Watershed Roads

Site 1

Site Name	Lagunitas Creek Watershed - Shafter Grade Road (road upgrade)
Location Corrected?	☐ *(Please make changes on attached quad map or attach additional maps.)*
Additional information about this site?	

Stream Order (circle one):	Distance to Materials (miles):	Site Accessibility (circle one):
1st order 2nd order 3rd order and above		easy - easy access average - partial vehicle access difficult - very limited/no vehicle access

Fill in blocks only for those tasks occurring at this site. Cost reported for each task should include labor, equipment, materials and in-kind contributions associated with this project site. If the project is ongoing, please estimate the final cost for each task.

Road Upgrade/Maintenance (Excluding Stream Culverts)

Road Upgrade Cost:	Miles Upgraded:	Upgrade Type (circle one):
		outsloping/insloping/crowning ditch relief culverts rolling dips waterbars resurfacing other

Road Decommissioning

Road Decom. Cost:	Miles Decommissioned:	# of Stream Crossings Treated:	Decommission Type (circle one): [a]
			complete obliteration partial closure only

[a] *Complete = full topographic obliteration. Partial = hydrologic obliteration. Closure only = close road to avoid need for regular maintenance; storm-proofing.*

Bank Stabilization (Excluding Riparian Planting)

Bank Stabilization Cost:	Streambank Treated (lineal feet):	Material Complexity (circle one): [a]	Excavation (circle one): [b]	Primary Stabilization Material (circle one): [c]
		minimal moderate substantial	minimal moderate extensive	wood rock/boulders both bioengineered other

[a] *Minimal = native channel gravel/rock, available onsite. Moderate = riprap, onsite plants. Substantial = large logs (>24" diameter), large rootwads, large toe rock, offsite plants.*

[b] *Minimal= hand tools. Moderate= small equipment, moderate excavation. Extensive= heavy equipment, slope reconstruction.*

[c] *Wood = logs/rootwads/tree bundles. Rock/Boulders = boulder/rock/cobble structures. Both = both wood and rock/boulder. Bioengineered = planting/placement of live plants/cuttings. Other = concrete/wire/geotextile fabric, etc.*

Fencing

Fencing Cost:	Fence Installed (lineal feet):	Material Complexity (circle one): [a]	Fence Electrified?
		simple average complex	☐

[a] *Simple = barb/hog wire, no gates, few posts. Average = livestock fence, metal, wood/metal corners, few gates, moderate # posts. Complex = smooth wire, New Zealand/curtan type, deer exclusion.*

CHRPD SiteID: 7003849 Site 1 - Page 1

Instream Structure Installation

Instream Structures Cost:	Number of Structures:	Stream Length Treated (miles):	Materials Onsite?	Primary Structure Material (circle one):[a]
			☐	wood rock/boulders both bioengineered other

Rock Size (tons per boulder):	Wood Diameter (inches):

[a] *Wood = logs/rootwads/tree bundles. Rock/Boulders = boulder/rock/cobble structures. Both = both wood and rock/boulder. Bioengineered = planting/placement of live plants/cuttings. Other = concrete/wire/geotextile fabric, etc.*

Culvert Replacement (Excluding Road Decommissioning Projects)

Culvert Replacement Cost:	Diameter of New Culvert (inches):	Culvert or Bridge Length (feet):	Construction (circle one):
			onsite precast

Fill Excavated (cubic yards):	# of Culverts:	Road Over Culvert (circle one):	Culvert Type (circle one):
		forest road minor 2 lane major 2 lane highway/4+ lanes	corrugated steel pipe SSP open bottom arch open-bottom concrete box/arch closed concrete box concrete circular or arch pipe log/wood bridge

Culvert Improvement (Excluding Road Decommissioning)

Improvement Cost:	Type of Improvement (circle one):	Weir Installed? (circle one):	Culvert Length (feet):
	Washington baffles, metal Washington baffles, wood CMP steel ramp baffles Other	Log weir Boulder weir None	

Riparian Planting (Excluding Road Decommissioning Projects)

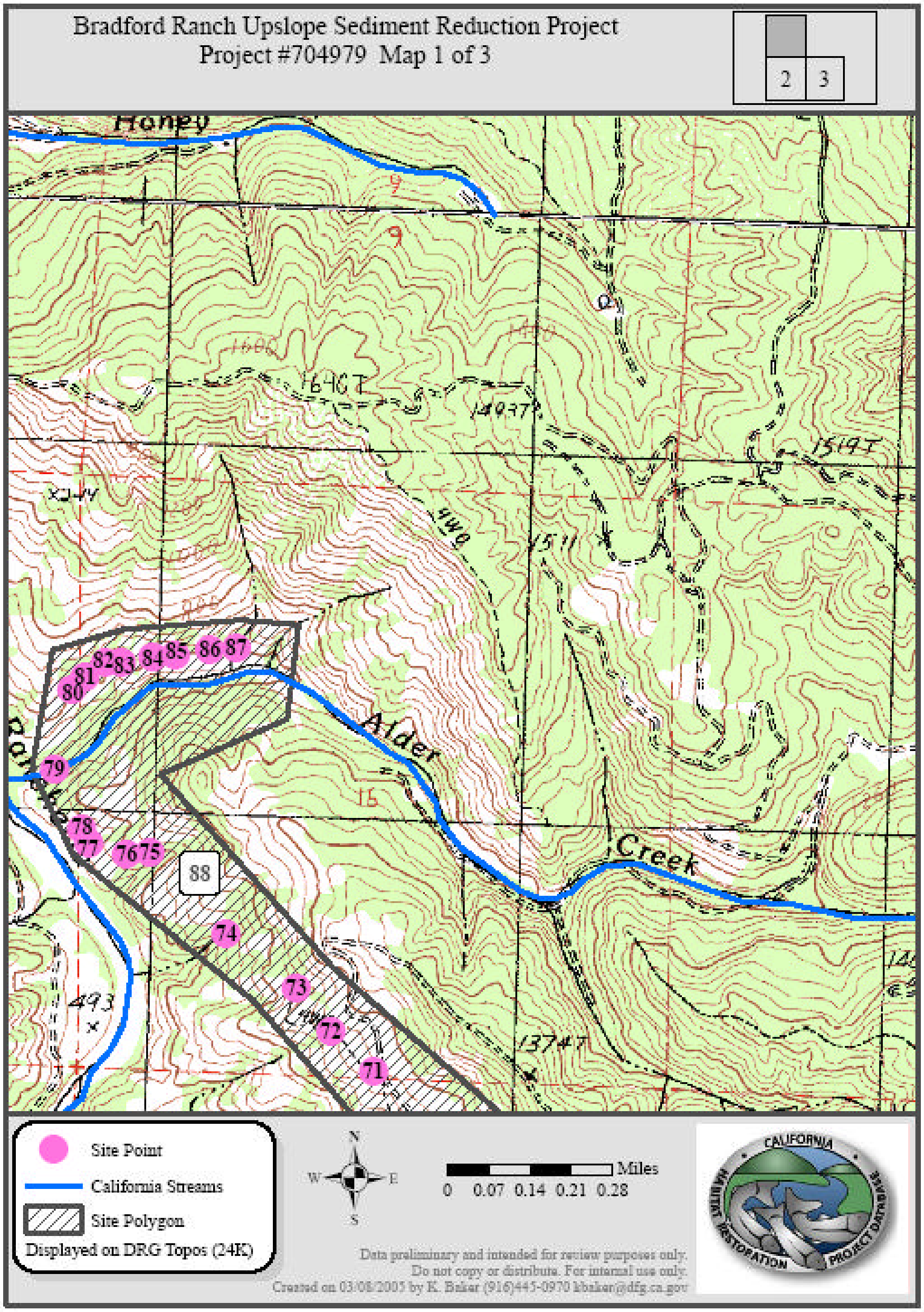
Riparian Planting Cost:	Area Planted (acres):	Trees Planted:	Plant Material Cost:[a]
			minimal moderate substantial

Site Preparation Difficulty:[b]	Irrigation (circle one):	Protection (circle one):
easy average difficult very difficult	drip irrigation hand irrigation none	chemical tubing shade protection none

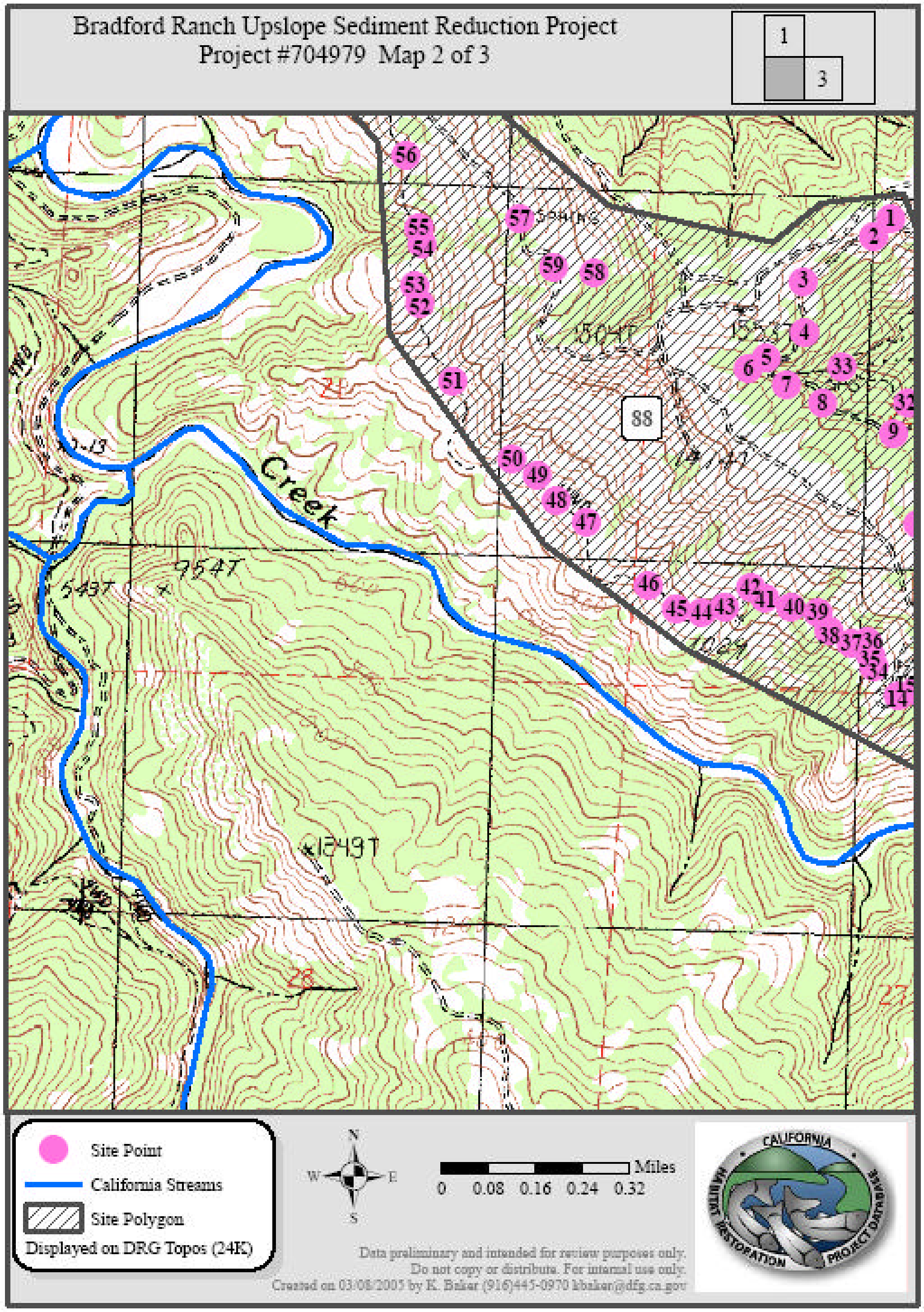
[a] *Minimal = bare root, native materials readily available, materials donated - in-kind cost not reported. Moderate = bare root, weed block, landscape fabric, mulch. Substantial = 1-5+ gal plants; weed block, landscape fabric/mulch, most materials purchased, native material not readily available or grown from seed.*

[b] *Easy = small debris/duff removal, slight sloping. Average = pasture sod removal. Difficult = non-native removal, machine labor. Very Difficult = non-native removal, hand labor.*

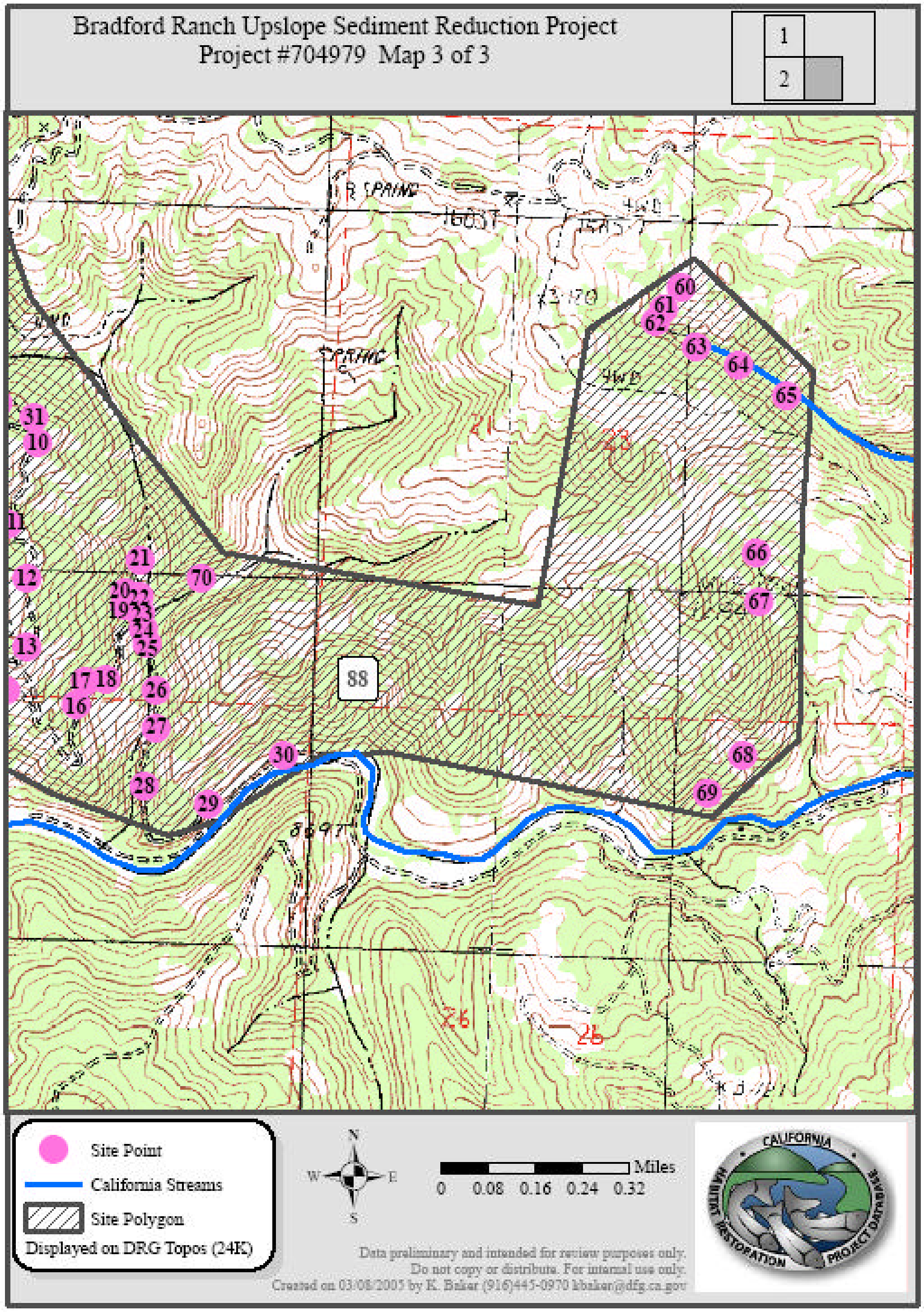
Example Map From Third Mailing:



Bradford Ranch Upslope Sediment Reduction Project
Project #704979 Map 2 of 3



Bradford Ranch Upslope Sediment Reduction Project
Project #704979 Map 3 of 3



Example Project Form From Third Mailing:

Project Form

<u>Bradford Ranch Upslope Sediment Reduction Project</u>

Gray fields: please write in any corrections or additions. *White fields: please write in requested information.*

Project ID	**704979**	
Number of Sites	88	*Number of locations where work was performed.*
Begin Year	2003	*The year work on the project began.*
Total Cost	$211,101.00	*(Includes labor, equipment, materials and in-kind contributions associated with this project.)*
Purpose	Decommission and upgrade 9.5 miles of road segments (2.4 miles decommissioned, 7.1 miles upgraded), saving an estimated 15,088 cubic yards of sediment from entering the watershed.	
Contact Name	Patty Madigan	
Title		
Agency	Mendocino County Resource Conservation District	
Address	405 South Orchard Avenue, Ukiah, CA 95482	
Phone	707-964-0395	
Fax	(707) 468-5278	
Email	pmad@mcn.org	
Experience		*Approximately how many similar projects has the contractor worked on?*
Permitting Cost:		*If known, please provide the (approximate) permitting cost for this project.*
Planning and Design Cost:		*If known, please provide the (approximate) cost of planning and design for this project.*
Status (circle one)	Proposed In progress Completed	If the project is in progress, please indicate the percent completed:
Prevailing Wages Required?	☐	*Check this box if you are required to pay prevailing wages on this project.*

Example Site Form From Third Mailing:

Project ID or Name:

Site ID: *(The label for the site on the provided map.)*

Site Name

Location Corrected? ☐ *(Please make changes on attached quad map or attach additional maps.)*

Additional information about this site?

Stream Order (circle one):	Distance to Materials (miles):	Site Accessibility (circle one):
1st order 2nd order 3rd order and above		easy - easy access average - partial vehicle access difficult - very limited/no vehicle access

Fill in blanks only for those tasks occurring at this site. Cost reported for each task should include labor, equipment, materials and in-kind contributions associated with this project site. If the project is ongoing, please estimate the final cost for each task.

Road Upgrade/Maintenance (Excluding Stream Culverts)

Road Upgrade Cost:	Miles Upgraded:	Upgrade Type (circle one):
		outsloping/insloping/crowning ditch relief culverts rolling dips waterbars resurfacing other

Road Decommissioning

Road Decom. Cost:	Miles Decommissioned:	# of Stream Crossings Treated:	Decommission Type (circle one):[a]
			complete obliteration partial closure only

[a] *Complete = full topographic obliteration. Partial = hydrologic obliteration. Closure only = close road to avoid need for regular maintenance; storm-proofing*

Bank Stabilization (Excluding Riparian Planting)

Bank Stabilization Cost:	Streambank Treated (lineal feet):	Material Complexity (circle one):[a]	Excavation (circle one):[b]	Primary Stabilization Material (circle one):[c]
		minimal moderate substantial	minimal moderate extensive	wood rock/boulders both bioengineered other

[a] *Minimal = native channel gravel/rock, available onsite. Moderate = riprap, onsite plants. Substantial = large logs (>24" diameter), large rootwads, large rip rock, offsite plants.*

[b] *Minimal = hand tools. Moderate = small equipment, moderate excavation. Extensive = heavy equipment, slope reconstruction.*

[c] *Wood = logs/rootwads/tree bundles. Rock/Boulders = boulder/rock/cobble structures. Both = both wood and rock/boulder. Bioengineered = planting/placement of live plants/cuttings. Other = concrete/wire/geotextile fabric, etc.*

Fencing

Fencing Cost:	Fence Installed (lineal feet):	Material Complexity (circle one):[a]	Fence Electrified?
		simple average complex	☐

[a] *Simple = barb/hog wire, no gates, few posts. Average = livestock fence, metal/wood/wood corners, few gates, moderate # posts. Complex = smooth wire, New Zealand/cattle type, deer exclusion.*

OVER

Page 1

Project ID or Name:	
Site ID:	*(The label for the site on the provided map.)*

Instream Structure Installation

Instream Structures Cost:	Number of Structures:	Stream Length Treated (miles):	Materials Onsite?	Primary Structure Material (circle one):[a]
			☐	wood rock/boulders both bioengineered other

Rock Size (tons per boulder):	Wood Diameter (inches):

[a] *Wood = logs/rootwads/tree bundles. Rock/Boulders = boulder/rock/cobble structures. Both = both wood and rock/boulder. Bioengineered = planting/placement of live plants/cuttings. Other = concrete/wire/geotextile fabric, etc.*

Culvert Replacement (Excluding Road Decommissioning Projects)

Culvert Replacement Cost:	Diameter of New Culvert (inches):	Culvert or Bridge Length (feet):	Construction (circle one):
			onsite precast

Fill Excavated (cubic yards):	# of Culverts:	Road Over Culvert (circle one):	Culvert Type (circle one):
		forest road minor 2 lane major 2 lane highway/4+ lanes	corrugated steel pipe SSP open bottom arch open-bottom concrete box/arch closed concrete box concrete circular or arch pipe log/wood bridge

Culvert Improvement (Excluding Road Decommissioning)

Improvement Cost:	Type of Improvement (circle one):	Weir Installed? (circle one):	Culvert Length (feet):
	Washington baffles, metal Washington baffles, wood CMP steel ramp baffles Other	Log weir Boulder weir None	

Riparian Planting (Excluding Road Decommissioning Projects)

Riparian Planting Cost:	Area Planted (acres):	Trees Planted:	Plant Material Cost: [a]
			minimal moderate substantial

Site Preparation Difficulty:[b]	Irrigation (circle one):	Protection (circle one):
easy average difficult very difficult	drip irrigation hand irrigation none	chemical tubing shade protection none

[a] *Minimal = bare root, native materials readily available, materials donated - in-kind cost not reported. Moderate = bare root, weed block, landscape fabric, mulch. Substantial = 1-5+ gal plants; weed block, landscape fabric/mulch, most materials purchased, native material not readily available or grown from seed.*

[b] *Easy = small debris/duff removal, slight sloping. Average = pasture sod removal. Difficult = non-native removal, machine labor. Very Difficult = non-native removal, hand labor.*

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Example Site List From Third Mailing:

SITE LIST

Contact : Patty Madigan

Project Name: Bradford Ranch Upslope Sediment Reduction Project

Site Code	SiteName
1	Rancheria Creek Watershed - Logging Road site 301 (stream-crossing decommissioning)
2	Rancheria Creek Watershed - Logging Road site 302 (stream-crossing decommissioning)
3	Rancheria Creek Watershed - Logging Road site 303 (stream-crossing decommissioning)
4	Rancheria Creek Watershed - Logging Road site 304 (stream-crossing decommissioning)
5	Rancheria Creek Watershed - Logging Road site 305 (stream-crossing decommissioning)
6	Rancheria Creek Watershed - Logging Road site 306 (stream-crossing decommissioning)
7	Rancheria Creek Watershed - Logging Road site 307 (stream-crossing upgrade)
8	Rancheria Creek Watershed - Logging Road site 310 (stream-crossing upgrade)
9	Rancheria Creek Watershed - Logging Road site 311 (culvert upgrade)
10	Rancheria Creek Watershed - Logging Road site 312 (stream-crossing upgrade)
11	Rancheria Creek Watershed - Logging Road site 314 (stream-crossing upgrade)
12	Rancheria Creek Watershed - Logging Road site 316 (road upgrade)
13	Rancheria Creek Watershed - Logging Road site 317 (road upgrade)
14	Rancheria Creek Watershed - Hell Canyon Road site 318 (road upgrade)
15	Rancheria Creek Watershed - Hell Canyon Road site 319 (road upgrade)
16	Rancheria Creek Watershed - Hell Canyon Road site 320 (road upgrade)
17	Rancheria Creek Watershed - Hell Canyon Road site 321 (road upgrade)
18	Rancheria Creek Watershed - Hell Canyon Road site 322 (road upgrade)
19	Rancheria Creek Watershed - Hell Canyon Road site 323 (road upgrade)
20	Rancheria Creek Watershed - Hell Canyon Road site 324 (road upgrade)
21	Rancheria Creek Watershed - Hell Canyon Road site 325 (road upgrade)
22	Rancheria Creek Watershed - Hell Canyon Road site 326 (road upgrade)
23	Rancheria Creek Watershed - Hell Canyon Road site 327 (road upgrade)
24	Rancheria Creek Watershed - Hell Canyon Road site 328 (road upgrade)
25	Rancheria Creek Watershed - Hell Canyon Road site 329 (road upgrade)
26	Rancheria Creek Watershed - Hell Canyon Road site 331 (road upgrade)
27	Rancheria Creek Watershed - Hell Canyon Road site 332 (road upgrade)
28	Rancheria Creek Watershed - Hell Canyon Road site 333 (road upgrade)
29	Rancheria Creek Watershed - Hell Canyon Road site 334 (road upgrade)
30	Rancheria Creek Watershed - Hell Canyon Road site 335 (road upgrade)
31	Rancheria Creek Watershed - North Fork Hell Canyon Road site 338 (road upgrade)
32	Rancheria Creek Watershed - North Fork Hell Canyon Road site 339 (road upgrade)
33	Rancheria Creek Watershed - North Fork Hell Canyon Road site 340 (stream-crossing decommissioning)
34	Rancheria Creek Watershed - Shenandoah Road site 344 (road upgrade)
35	Rancheria Creek Watershed - Shenandoah Road site 345 (road upgrade)
36	Rancheria Creek Watershed - Shenandoah Road site 346 (road upgrade)
37	Rancheria Creek Watershed - Shenandoah Road site 347 (road upgrade)
38	Rancheria Creek Watershed - Shenandoah Road site 348 (road upgrade)
39	Rancheria Creek Watershed - Shenandoah Road site 349 (road upgrade)
40	Rancheria Creek Watershed - Shenandoah Road site 350 (road upgrade)
41	Rancheria Creek Watershed - Shenandoah Road site 351 (road upgrade)
42	Rancheria Creek Watershed - Shenandoah Road site 352 (culvert upgrade)

SITE LIST

Contact: Patty Madigan

43	Rancheria Creek Watershed - Shenandoah Road site 233 (road upgrade)
44	Rancheria Creek Watershed - Shenandoah Road site 234 (road upgrade)
45	Rancheria Creek Watershed - Shenandoah Road site 235 (road upgrade)
46	Rancheria Creek Watershed - Shenandoah Road site 236 (culvert upgrade)
47	Rancheria Creek Watershed - Shenandoah Road site 237 (road upgrade)
48	Rancheria Creek Watershed - Shenandoah Road site 238 (stream crossing upgrade)
49	Rancheria Creek Watershed - Shenandoah Road site 239 (road upgrade)
50	Rancheria Creek Watershed - Shenandoah Road site 250 (road upgrade)
51	Rancheria Creek Watershed - Shenandoah Road site 252 (road upgrade)
52	Rancheria Creek Watershed - Shenandoah Road site 253 (road upgrade)
53	Rancheria Creek Watershed - Shenandoah Road site 254 (road upgrade)
54	Rancheria Creek Watershed - Shenandoah Road site 255 (road upgrade)
55	Rancheria Creek Watershed - Shenandoah Road site 266 (road upgrade)
56	Rancheria Creek Watershed - Shenandoah Road site 267 (road upgrade)
57	Rancheria Creek Watershed - Snowshed Road site 268 (road upgrade)
58	Rancheria Creek Watershed - Snowshed Road site 269 (road upgrade)
59	Rancheria Creek Watershed - Snowshed Road site 270 (road upgrade)
60	Rancheria Creek Watershed - Pepperwood Canyon Road site 181 (culvert upgrade)
61	Rancheria Creek Watershed - Pepperwood Canyon Road site 182 (culvert upgrade)
62	Rancheria Creek Watershed - Pepperwood Canyon Road site 183 (culvert upgrade)
63	Rancheria Creek Watershed - Pepperwood Canyon Road site 184 (culvert upgrade)
64	Rancheria Creek Watershed - Pepperwood Canyon Road site 185 (culvert upgrade)
65	Rancheria Creek Watershed - Pepperwood Canyon Road site 186 (road upgrade)
66	Rancheria Creek Watershed - Pocket Road site 287 (road upgrade)
67	Rancheria Creek Watershed - Deep Pocket Spur site 288 (road upgrade)
68	Rancheria Creek Watershed - Deep Pocket Spur site 289 (culvert upgrade)
69	Rancheria Creek Watershed - Deep Pocket Spur site 290 (culvert upgrade)
70	Rancheria Creek Watershed - Loving Hall Canyon Spur Road site 336 (road decommissioning)
71	Rancheria Creek Watershed - Old Alder Creek Road site 271 (stream crossing decommissioning)
72	Rancheria Creek Watershed - Old Alder Creek Road site 272 (road upgrade)
73	Rancheria Creek Watershed - Old Alder Creek Road site 273 (stream crossing decommissioning)
74	Rancheria Creek Watershed - Old Alder Creek Road site 274 (stream crossing decommissioning)
75	Rancheria Creek Watershed - Old Alder Creek Road site 276 (stream crossing decommissioning)
76	Rancheria Creek Watershed - Old Alder Creek Road site 277 (stream crossing decommissioning)
77	Rancheria Creek Watershed - Old Alder Creek Road site 278 (stream crossing decommissioning)
78	Rancheria Creek Watershed - Old Alder Creek Road site 279 (stream crossing decommissioning)
79	Rancheria Creek Watershed - Alder Creek Road site 303 (road upgrade)
80	Rancheria Creek Watershed - Alder Creek Road site 304 (stream crossing decommissioning)
81	Rancheria Creek Watershed - Alder Creek Road site 305 (stream crossing decommissioning)
82	Rancheria Creek Watershed - Alder Creek Road site 306 (stream crossing decommissioning)
83	Rancheria Creek Watershed - Alder Creek Road site 307 (stream crossing decommissioning)
84	Rancheria Creek Watershed - Alder Creek Road site 308 (stream crossing decommissioning)
85	Rancheria Creek Watershed - Alder Creek Road site 309 (stream crossing decommissioning)
86	Rancheria Creek Watershed - Alder Creek Road site 310 (stream crossing decommissioning)

SITE LIST

Contact : Patty Madigan

87	Rancheria Creek Watershed - Alder Creek Road site 33 (stream crossing decommissioning)
88	Rancheria Creek Watershed - road decommissioning, upgrading

Appendix 2. Suggested Database Structure and Definitions

Here we present a possible database structure with field definitions for collecting detailed restoration project information. A database schematic is presented in Figure, and the tables that follow contain descriptions of the fields. This structure is intended as a potential addition to the CHRPD. Additional restoration categories for which further data are desired (such as barrier removal, fish ladders, fish screens, water conservation measures, and land acquisition) could easily be added. General suggestions include the following:

- Maintain separate cost and details data for each task at each site.
- Maintain accurate spatial data for each site. Accurate spatial location of the data is necessary for geographically relating sites to socioeconomic and environmental variables.
- Collect data as continuous variables whenever possible. Continuous variables are more flexible than categorical variables because they can be converted to categorical variables using a variety of category definitions. Data collected in a limited number of categories cannot be reclassified if there is a need to change the category definitions in the future. In the structure below, we attempted to use continuous variables as much as possible, but it still might be possible to substitute additional continuous variables for some of the categorical variables we suggest. This could be explored as part of the validation process for any final data collection protocol.

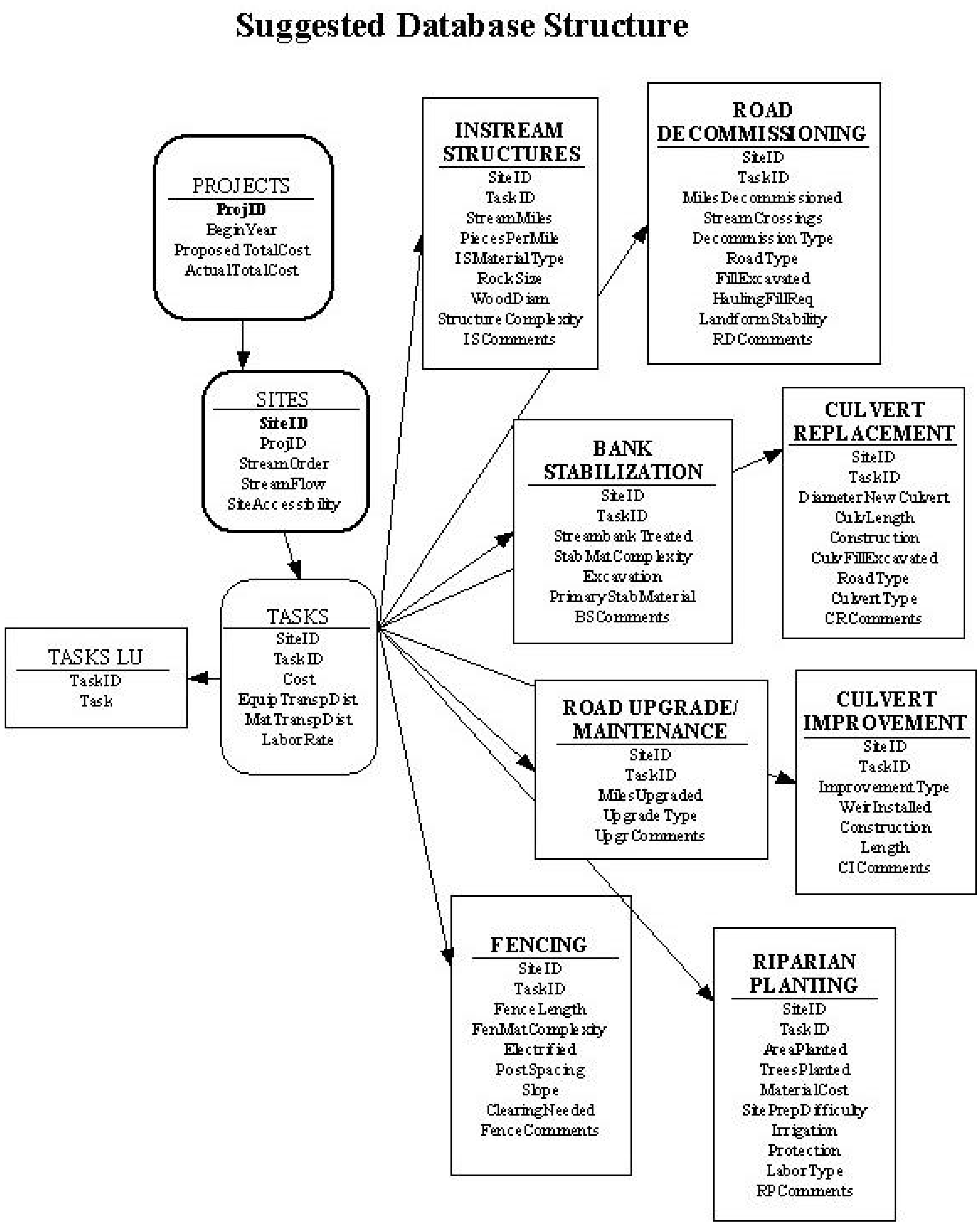

Figure 122. Schematic of a proposed database structure for collecting detailed restoration project data.

Projects Table: Table (MitProject) and fields currently exist in the CHRPD

Sites Table: Existing table (MitLocation) in the CHRPD with fields added

Field Name	Field Description	Units	Details
SiteID	Unique Site ID	N/A	Existing field
ProjID	Unique Project ID	N/A	Existing field
BeginYear	Year the work began	N/A	
StreamOrder	Stream Order	N/A	Stream Order – select from: 1^{st} order, 2^{nd} order, 3^{rd} order and above.
StreamFlow	Stream flow	CFS	
SiteAccessibility	Site Accessibility	N/A	Suggested levels: Easy = easy access; Average = partial vehicle access; Difficult = very limited/no vehicle access

Tasks Table

Field Name	Field Description	Units	Details
SiteID	Site ID	N/A	Existing field; links to Site Table
TaskID	Task ID	N/A	Identifies the restoration tasks; links (with SiteID) to task-specific tables. Definitions stored in separate Tasks lookup table (LU) Suggested tasks: 1=Fencing Projects; 2=Riparian Planting; 3=Culvert Replacement; 4=Existing Culvert Improvement; 5=Instream Structures; 6=Bank Stabilization; 7=Road Decommissioning; 8=Road Surface Upgrade/Maintenance; 9=Land Acquisition; 10=Water Conservation Measures; 11=Fish Screens; 12=Fish Ladders; 13=Barrier Removal
Cost	Site and task specific cost	dollars	Cost including labor, equipment, materials, and in-kind contributions
EquipTranspDist	Transportation distance for equipment	miles	How far must equipment be transported to the site?
MatTranspDist	Transportation distance for materials	miles	How far must materials be transported to the site?
LaborRate	Labor rate per hour	dollars	

Instream Structures Table

Field Name	Field Description	Units	Details
SiteID	Site ID	N/A	Existing field; links to Site Table and links (with TaskID) to Tasks Table
TaskID	Task ID	N/A	Identifies the restoration tasks; links (with SiteID) to Tasks Table. Suggested task: 5=Instream Structures
StreamMiles	Number of miles of stream treated	miles	This field should only be used for very simple instream structures or woody debris placement. Complex structures should each be assigned a separate site.
PiecesPerMile	Pieces of wood or number of boulders per mile	N/A	This field should only be used for very simple instream structures or woody debris placement. Complex structures should each be assigned a separate site.
ISMaterialType	Primary material type of instream structures	miles	Suggested materials: wood = logs/rootwads/tree bundles; rock/boulder = boulder/rock/cobble structures; both = both wood and rock; cement

RockSize	Size of boulders used	tons/boulder	
WoodDiam	Diameter of wood used	inches	
StructureComplexity	Complexity of structure installed	N/A	Suggested complexity categories need to be defined: simple; average; complex
ISComments	Comments	N/A	Explanations of any unusual aspects to the data

Road Decommissioning Table

Field Name	Field Description	Units	Details
SiteID	Site ID	N/A	Existing field; links to Site Table and links (with TaskID) to Tasks Table
TaskID	Task ID	N/A	Identifies the restoration tasks; links (with SiteID) to Tasks Table. Suggested task: 7=Road Decommissioning
MilesDecommissioned	Number of miles of road decommissioned	miles	
StreamCrossings	Number of stream crossings treated	N/A	
DecommissionType	Type of road decommissioning	N/A	Suggested types: closure only = close road to avoid need for regular maintenance, storm-proofing; partial = hydrologic obliteration; complete obliteration = full topographic obliteration
RoadType	Type of road	N/A	Suggested types: Minimum = ranch roads; Moderate = skid roads; Maximum = Asphalt, legacy, Humboldt crossings
FillExcavated	Amount of fill excavated	cubic yards	
HaulingFillRequired	Is hauling of fill necessary?	N/A	Suggested categories: yes; no
LandformStability	Geology/landform stability/past failures from road system		Suggested categories: Infrequent/minor; Moderate; Frequent/severe
RDComments	Comments	N/A	Explanations of any unusual aspects to the data

Bank Stabilization Table

Field Name	Field Description	Units	Details
SiteID	Site ID	N/A	Existing field; links to Site Table and links (with TaskID) to Tasks Table
TaskID	Task ID	N/A	Identifies the restoration tasks; links (with SiteID) to Tasks Table. Suggested task: 6=Bank Stabilization
StreambankTreated	Number of feet of streambank treated	feet	Linear feet of bank treated
StabMatComplexity	Complexity of stabilization materials used	N/A	Suggested complexity categories need to be defined: minimal; moderate; substantial
Excavation	Amount of excavation	cubic yards	
PrimaryStabMaterial	Primary material used for stabilization	N/A	Suggested materials: wood = logs/rootwads/tree bundles; rock/boulder = boulders/rock; both = both wood and rock; bioengineered = planting/placement of live plants/cuttings

BSComments	Comments	N/A	Explanations of any unusual aspects to the data

Culvert Replacement Table

Field Name	Field Description	Units	Details
SiteID	Site ID	N/A	Existing field; links to Site Table and links (with TaskID) to Tasks Table
TaskID	Task ID	N/A	Identifies the restoration tasks; links (with SiteID) to Tasks Table. Suggested task: 3=Culvert Replacement
DiameterNewCulvert	Diameter of new culver	inches	
CulvLength	Length of culvert	feet	
Construction	Was culvert constructed onsite or precast?	N/A	Suggested categories: onsite; precast
CulvFillExcavated	Amount of fill excavated	cubic yards	
RoadType	Type of road above culvert	N/A	Suggested categories: Infrequent/minor; Moderate; Frequent/severe
CulvertType	Type of culvert installed	N/A	Suggested types: corrugated steel pipe; structural steel pipe (SSP) open bottom arch; open-bottom concrete box/arch; or bridge
CRComments	Comments	N/A	Explanations of any unusual aspects to the data

Road Upgrade/Maintenance Table

Field Name	Field Description	Units	Details
SiteID	Site ID	N/A	Existing field; links to Site Table and links (with TaskID) to Tasks Table
TaskID	Task ID	N/A	Identifies the restoration tasks; links (with SiteID) to Tasks Table. Suggested task: 8=Road Surface Upgrade/Maintenance
MilesUpgraded	Number of miles of road upgraded	miles	
UpgradeType	Type of road upgrade	N/A	Suggested categories: outsloping/insloping/crowning; ditch relief culverts (drc); rolling dips; waterbars; resurfacing; or other
UpgrComments	Comments	N/A	Explanations of any unusual aspects to the data

Culvert Improvement Table

Field Name	Field Description	Units	Details
SiteID	Site ID	N/A	Existing field; links to Site Table and links (with TaskID) to Tasks Table
TaskID	Task ID	N/A	Identifies the restoration tasks; links (with SiteID) to Tasks Table. Suggested task: 4=Existing Culvert Improvement
ImprovementType	Type of culvert improvement	N/A	Suggested categories: Washington baffles, metal; Washington baffles, wood; CMP steel ramp baffles; other
WeirInstalled	Was a weir installed?	N/A	Suggested categories: yes/no
Construction	Was culvert	N/A	Suggested categories: onsite; precast

	constructed onsite or precast?		
Length	Length of culvert improved	feet	
CIComments	Comments	N/A	Explanations of any unusual aspects to the data

Fencing Table

Field Name	Field Description	Units	Details
SiteID	Site ID	N/A	Existing field; links to Site Table and links (with TaskID) to Tasks Table
TaskID	Task ID	N/A	Identifies the restoration tasks; links (with SiteID) to Tasks Table. Suggested task: 1=Fencing Projects
FenceLength	Linear feet of fence installed	feet	
FenMatComplexity	Complexity of fencing	N/A	Suggested levels: simple = barb or hog wire, no gates, few posts; average = livestock fence, metal, wood or metal corners, few gates, moderate number of posts; complex = smooth wire, new Zealand type, deer exclusion, curtain type
Electrified	Was the fence electrified?	N/A	Suggested categories: yes; no
PostSpacing	Spacing between posts	feet	
Slope	Average slope of the terrain	degrees	
ClearingNeeded	Amount of clearing of vegetation needed	N/A	Suggested clearing categories need to be defined: light; average; heavy
FenceComments	Comments	N/A	Explanations of any unusual aspects to the data

Riparian Planting Table

Field Name	Field Description	Units	Details
SiteID	Site ID	N/A	Existing field; links to Site Table and links (with TaskID) to Tasks Table
TaskID	Task ID	N/A	Identifies the restoration tasks; links (with SiteID) to Tasks Table. Suggested task: 2=Riparian Planting
AreaPlanted	Area planted	acres	
TreesPlanted	Number of trees planted	N/A	
MaterialCost	Was the fence electrified?	N/A	Suggested categories: yes; no
SitePrepDifficulty	Difficulty of site preparation	N/A	Suggested categories: easy = flat/light clearing, soil easily tilled; average = average slope/average clearing, average soil; difficult = steep/heavy clearing, soil difficult to till
Irrigation	Type of irrigation used	N/A	Suggested categories: easy = driwater/time release, drip irrigation, hand irrigation, or none
Protection	Plant protection used	N/A	Suggested categories: chemical; tubing; shade protection; none
LaborType	Type of labor used	N/A	Suggested categories: volunteer; conservation corps; contracted

RPComments	Comments	N/A	Explanations of any unusual aspects to the data

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